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THE IRON AND STEEL MAGAZINE

SUCCESSOR TO THE METALLOGRAPHIST

A MONTHLY PUBLICATION DEVOTED TO THE IRON AND STEEL INDUSTRY

EDITED BY
ALBERT SAUVEUR

VOLUME X
JULY TO DECEMBER, 1905

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ROTCH BUILDING
CAMBRIDGE, MASSACHUSETTS

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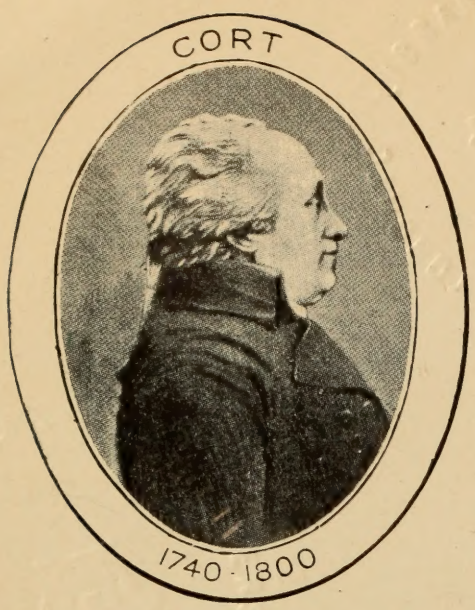
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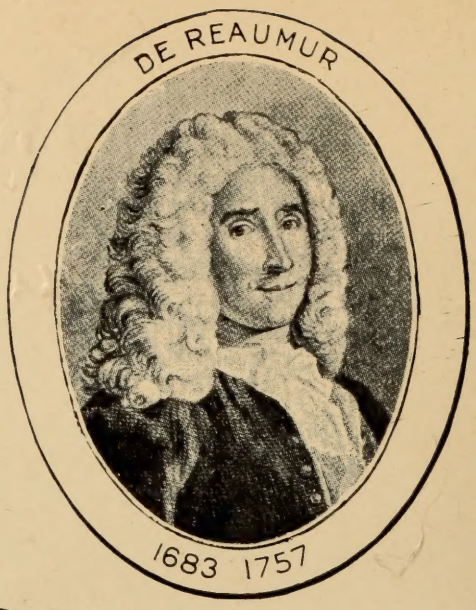
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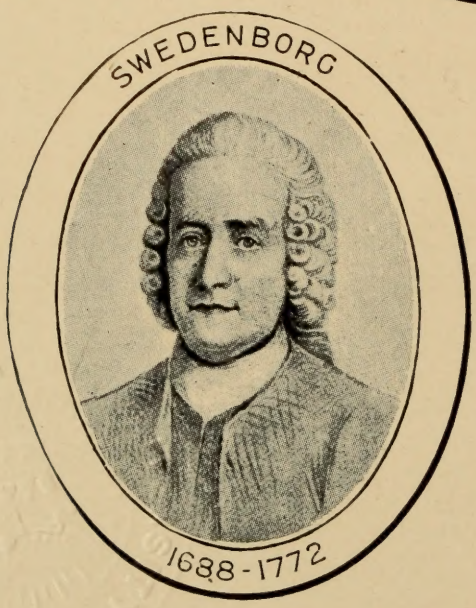
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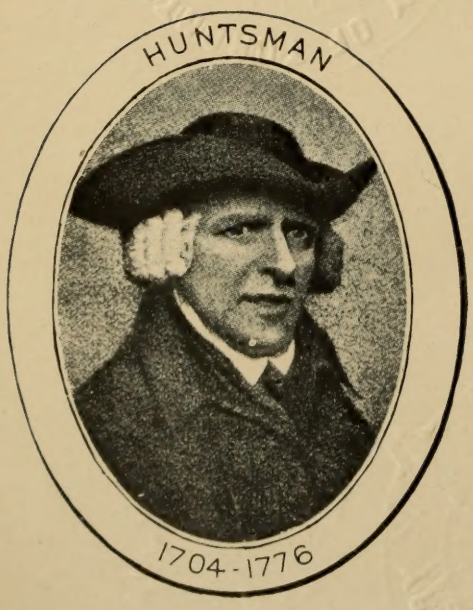
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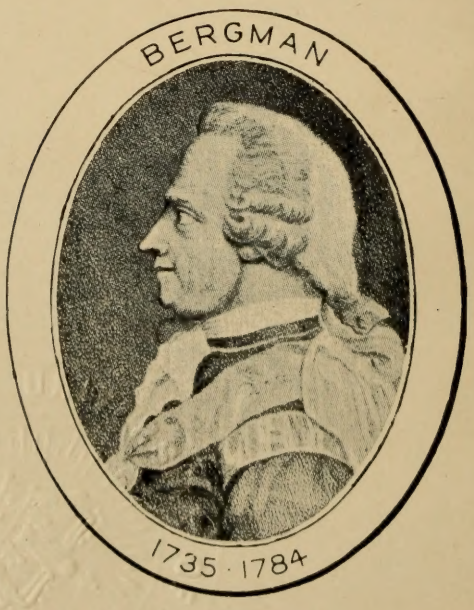
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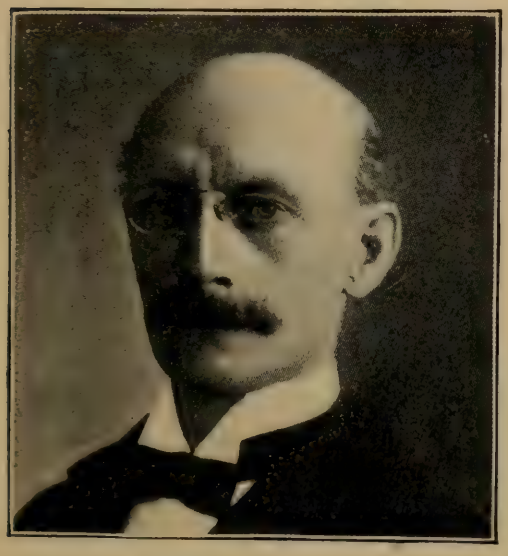
". . . . . Je veux au mond publier
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Vol. X July, 1905 No. 1

THE APPLICATION OF DRY-AIR BLAST (Supplementary Paper)

By JAMES GAYLEY, New York

IT is to be regretted that the data respecting the use of dry-air blast, which were presented to the Institute at its meeting in the United States, in October, should have been restricted to the period from August 25 to September 9 inclusive, and from September 17 to 30 inclusive. In order to present the paper at all it was found necessary to limit the record of operations to the period above stated. In the discussion of the paper it would appear from the conclusions of some participating therein, that they have been placed at some disadvantage in considering the economies obtained through the use of dry-air blast, by reason of the data covering such a short period. It is the purpose of this communication to present in detail the record of operations of the Isabella Furnaces from November, 1904, to March, 1905, inclusive, as shown by the furnace records.



The month of October is not included, as the furnace using dry-air blast was stopped several times for repairs, and while

TABLE I.—*November.*

Date.	Grains of Moisture.				Temperature.				Gas Analysis.	
	In Atmosphere.		In Dry Blast.		Atmosphere.		Dry Blast.		CO.	CO_2.
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.		
Nov. 1	2·53	2·74	1·15	1·05	51	47	20	17	25·8	12·6
,, 2	2·82	2·75	1·10	1·02	50	50	18	16	25·6	12·2
,, 3	2·64	2·59	1·05	1·01	47	45	16	16	23·6	14·0
,, 4	2·18	2·44	1·06	1·07	52	50	16	19	23·0	15·0
,, 5	2·58	1·98	1·13	1·01	54	44	17	19	...	...
,, 6	1·69	1·79	0·94	1·06	45	44	15	19	...	...
,, 7	1·86	2·35	1·05	1·04	43	41	17	20	22·8	14·0
,, 8	2·42	2·43	1·04	1·04	45	44	20	20	...	...
,, 9	2·30	2·39	1·09	1·02	46	42	19	19	...	...
,, 10	2·52	2·49	1·07	1·05	44	45	19	20	22·8	14·0
,, 11	1·69	1·68	1·00	1·04	44	39	18	20	...	...
,, 12	1·50	1·73	1·07	1·02	42	47	20	22	..	...
,, 13	1·88	1·79	1·04	1·00	43	44	21	22	...	...
,, 14	1·56	1·59	1·04	0·95	44	41	20	21	23·8	13·8
,, 15	1·89	1·91	1·07	1·06	45	45	20	22	...	...
,, 16	2·01	1·91	1·11	1·02	49	39	20	21	20·6	13·0
,, 17	1·74	1·85	1·01	1·05	41	39	18	22	...	...
,, 18	2·04	2·25	1·13	1·09	48	48	21	22	23·4	14·0
,, 19	2·24	2·35	1·10	1·09	48	50	21	22	..	...
,, 20	2·74	3·03	1·16	1·04	59	59	22	20	..	..
,, 21	1·96	1·85	0·98	0·96	52	39	18	20	23·2	16·0
,, 22	2·06	2·02	1·05	1·03	43	40	20	20	...	..
,, 23	2·21	2·18	1·03	1·01	44	51	20	21	24·0	12·0
,, 24	2·43	1·81	1·07	1·00	48	44	21	21	...	.
,, 25	1·62	1·32	0·94	0·99	43	44	22	21	24·8	12·0
,, 26	1·49	1·43	0·98	1·01	39	35	20	21	...	..
,, 27	1·01	0·90	0·93	0·81	33	29	19	17	...	...
,, 28	0·88	1·02	0·81	0·83	31	37	18	18	22·6	15·0
,, 29	2·33	2·30	1·07	1·03	56	49	21	20	..	..
,, 30	1·05	1·00	0·81	0·82	37	33	17	18	23·0	15·0
Average	1·99	1·99	1·03	1·01	46	43	19	20	23·5	13·8

The record of operations is as follows :—

	Average Daily Product.	Average Coke Consumption.	Blowing-Engines. Revolutions per Minute.	Average Temperature. Hot Blast.
	Tons.	Lbs.		Deg
No. 1 Furnace (Dry Air) .	447	1816	96	854
No. 3 Furnace (Natural Air)	386	2279	111	750

the record was a very good one considering these interruptions, yet it was not a continuous one.

The record for No. 1 Furnace using dry blast, and the comparison with No. 3 Furnace using normal blast for the month of November, 1904, is set forth in Table I.

TABLE II.—*December.*

Date.	Grains of Moisture.				Temperature.				Gas Analysis.	
	In Atmosphere.		In Dry Blast.		Atmosphere.		Dry Blast.		CO.	CO_2.
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.		
Dec. 1	1·13	1·37	0·98	1·07	35	36	20	21	23·4	13·6
,, 2	1·41	1·56	1·08	0·97	38	37	20	20	...	...
,, 3	1·56	1·46	1·02	0·96	35	34	20	20	...	...
,, 4	1·26	1·30	0·99	0·97	33	29	19	19	23·0	14·0
,, 5	1·34	1·39	0·97	0·98	31	36	18	20	23·0	14·0
,, 6	1·28	1·50	1·00	1·00	35	36	20	20	25·0	12·0
,, 7	1·70	1·67	1·10	0·99	39	40	20	20	...	...
,, 8	1·31	1·20	1·00	0·95	41	34	20	19	22·6	14·8
,, 9	1·12	1·11	0·93	0·85	32	29	18	18	24·8	14·4
,, 10	0·91	0·55	0·76	0·52	25	15	16	11	24·0	14·0
,, 11	0·55	0·80	0·43	0·44	15	23	7	10	...	...
,, 12	1·26	1·37	0·85	0·94	30	30	17	19	24·4	12·8
,, 13	1·04	0·83	0·93	0·64	29	23	18	14	23·0	13·6
,, 14	0·73	0·64	0·67	0·53	22	13	12	9	24·0	14·0
,, 15	0·74	0·78	0·53	0·56	22	20	8	10	...	...
,, 16	0·79	0·99	0·72	0·70	20	21	10	11	23·0	15·0
,, 17	1·39	1·65	0·79	1·02	29	34	14	20	...	...
,, 18	1·37	1·72	1·00	1·06	32	32	19	20	...	...
,, 19	1·81	1·35	1·11	0·96	35	31	21	18	22·3	15·0
,, 20	1·29	1·31	1·02	1·04	31	34	18	19	22·8	13·4
,, 21	1·34	1·27	1·07	1·00	31	30	19	18	22·4	13·6
,, 22	1·23	1·91	1·10	1·08	35	49	19	20	22·6	14·4
,, 23	2·44	3·50	1·35	1·54	53	53	23	27	...	...
,, 24	2·15	1·71	1·18	0·94	40	35	21	18	23·1	13·2
,, 25	2·19	2·31	0·96	1·03	37	38	17	19	...	...
,, 26	2·37	3·06	1·11	1·25	41	46	19	22	...	...
,, 27	3·91	2·23	1·41	1·11	58	48	24	21	...	...
,, 28	0·68	0·72	0·74	0·60	25	21	15	13	24·7	13·3
,, 29	0·82	0·94	0·67	0·69	25	29	13	13	24·2	13·0
,, 30	1·04	1·26	0·82	0·91	38	43	15	16	24·8	13·6
,, 31	1·55	2·22	0·96	1·11	47	51	19	22	...	...
Average	1·41	1·47	0·94	0·92	34	33	17	18	23·5	13·8

NOTE.—All temperatures are Fahrenheit, and tons are 2240 lbs. Gas analyses expressed in vols.

By a reference to my former paper it will be noted that the month of November is the beginning, in this part of the country, of the winter period, when the atmosphere decreases rapidly in humidity. The months of October and April being the transition months in the autumn and the spring respectively, furnaces

using natural air approach more closely, from November on, to the conditions obtained by the use of dry-air blast. The data given in Table I, with reference to grains of moisture and temperature, represent the average for the day, of observations taken hourly during the period indicated.

The temperature of the dry blast is from observations taken at the top of the refrigerator chamber, but this temperature is increased in the passage of the air from the refrigerator chamber to the blowing engines.

In Table II is shown the record of operations for the month of December, 1904, and in this record it is interesting to note the decrease in moisture as compared with November. In November the average moisture was 1.99 grains, while in December it was 1.45 grains, the maximum variation, however, being from 0.55 to 3.91 grains.

There is also a slight reduction in the grains of moisture in the dry air.

The air conduit pipe from the refrigerator chamber to blowing engine room was constructed to connect with four blowing-engines, and as only three engines were used in No. 1 Furnace, it was decided to connect the fourth engine with the dry-air conduit and apply it to No. 3 Furnace, thus making on No. 3 two engines with natural air and one engine with dry air. The comparison of the work of No. 1 with No. 3 Furnace, and the effect of one third of the engine revolutions supplying dry air to No. 3 Furnace, is shown as follows:

	Average Daily Product	Average Coke Consumption	Blowing Engines Revolutions per Minute	Average Temperature Hot Blast
	Tons	Lbs.		Deg.
No 1 Furnace:				
Dry Blast	455	1,823	96	877
No. 3 Furnace:				
Dec. 1–22 (Normal Blast)	400	2,309	(111)	(785)
Dec. 23–31 (⅓ Dry Blast)	461	2,140	....	....

Although one third of the engine revolutions supplied dry air, yet the weight of dry air was slightly in excess of one third the total quantity, by reason of the air being denser.

The result shown by the use of such a small quantity of dry air is remarkable, and is greater than was experienced when first applying the dry air to No. 1 Furnace in August. The

application of one third of the engine revolutions with dry air increased the weight of air delivered to the furnace, and at the same time the average temperature of hot blast increased 20°. The furnace at once began to drive more rapidly, and the burden was also increased. There was no deterioration in the grade of

TABLE III.—*January.*

Date.	Grains of Moisture.				Temperature.				Gas Analysis.	
	In Atmosphere.		In Dry Blast.		Atmosphere.		Dry Blast.		CO.	CO_2.
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.		
Jan. 1	2·61	2·75	1·19	1·14	53	51	22	20	.	...
,, 2	3·31	2·19	1·34	0·82	52	41	21	15	...	...
,, 3	0·98	0·52	0·50	0·45	27	18	9	9	24·8	13·0
,, 4	0·70	0·78	0·58	0·57	20	22	10	10	24·3	13·2
,, 5	1·09	1·34	0·73	0·78	29	33	13	14	23·0	14·2
,, 6	1·85	1·96	0·94	0·80	33	35	16	16	24·0	13·0
,, 7	1·49	1·19	0·81	0·68	32	29	15	14	23·4	13·0
,, 8	1·00	0·89	0·71	0·70	26	23	13	12	...	...
,, 9	0·97	1·72	0·69	0·84	25	31	12	15	..	...
,, 10	0·61	0·90	0·58	0·48	21	23	10	7	..	..
,, 11	1·65	2·89	0·66	0·81	31	45	9	12	.	...
,, 12	3·05	1·51	1·00	0·66	48	37	15	11	...	...
,, 13	1·00	0·86	0·68	0·48	31	27	10	8	...	...
,, 14	0·53	0·65	0·49	0·49	17	20	7	8	...	...
,, 15	0·77	0·63	0·59	0·45	24	19	9	7	...	...
,, 16	0·85	0·95	0·61	0·53	23	28	10	10	...	...
,, 17	1·08	1·23	0·65	0·64	31	34	12	12	...	...
,, 18	1·31	1·33	0·75	0·69	36	41	12	13	22·8	14·2
,, 19	2·05	1·96	0·86	0·86	42	42	15	16	...	...
,, 20	1·67	1·65	0·78	0·64	42	36	13	11	22·6	14·0
,, 21	1·87	2·15	0·76	0·75	40	39	12	13	. .	...
,, 22	1·43	0·79	0·77	0·48	35	25	13	9	...	...
,, 23	0·85	1·20	0·56	0·57	22	26	9	11	23·8	13·8
,, 24	1·44	0·97	0·64	0·51	29	23	12	9	...	...
,, 25	0·67	0·42	0·45	0·35	19	12	7	4	23·0	12·8
,, 26	0·47	0·69	0·38	0·42	15	17	5	6	22·2	13·0
,, 27	0·94	1·18	0·46	0·53	24	30	7	7	23·8	13·5
,, 28	0·69	0·38	0·50	0·27	23	9	8	2	22·6	14·8
,, 29	0·47	0·53	0·28	0·36	10	18	−1	3	...	...
,, 30	0·72	0·72	0·41	0·37	18	15	3	3	23·4	13·6
,, 31	0·99	1·22	0·50	0·55	22	28	5	8	23·3	15·7
Average	1·26	1·23	0·67	0·60	29	28	11	10	23·3	13·5

metal produced, in fact it was slightly better, as the silicon was higher and sulphur lower than in the preceding part of the month.

In Table III is set forth the record for January, 1905, whe in is found a further reduction in the humidity of the atmosphere.

On January 10, the dry blast was changed from No. 1 to No. 3 Furnace. Both furnaces were making the same grade of

iron for use in the basic open-hearth process. In the table below no account is taken of the period from the 11th to 14th inclusive, as this period was occupied in adjusting the dry blast and burden on both furnaces. The record of the burden on each furnace shows as follows:

	Weight of Coke in Charge Lbs.	Weight of Ore in Charge Lbs.
No. 1 Furnace:		
Jan. 1–10 (Dry Blast)	10,200	24,000
Jan. 15–31 (Normal Blast)	10,200	20,200
No. 3 Furnace:		
Jan. 1–10 (Normal Blast *) (Extra coke in charge)	10,200	20,200
Jan. 15–31 (Dry Blast)	10,200	23,600

During the period from January 1 to 10, when No. 3 Furnace was on normal blast, there was charged with the regular burden a small quantity of extra coke. This was taken off when the furnace was changed to dry blast, which would make the burden with dry blast for No. 3 Furnace correspond with No. 1 Furnace with dry blast. The result on each furnace, before and after the change in blast had been made, is as follows:

	Average Daily Product	Average Coke Consumption	Blowing Engines Revolutions per Minute	Average Temperature Hot Blast
No. 1 Furnace:	Tons	Lbs.		Deg.
Jan. 1–10 (Dry Blast)	428	1,825	96	869
Jan. 15–31 (Normal Blast)	414	2,340	111	771
No. 3 Furnace:				
Jan. 1–10 (Normal Blast)	410	2,351	111	716
Jan. 15–31 (Dry Blast)	432	1,811	96	80[illegible]

The ore mixture on No. 3 Furnace gave a yield in iron 1 per cent greater than the mixture on No. 1 Furnace. The purpose in changing the dry blast from No. 1 to No. 3 Furnace was to determine the economy on another furnace at a time which represented in that locality nearly the minimum of humidity in the atmosphere, the extreme variations being from 0.38 to 3.31 grains, with a monthly average of 1.25 grains of moisture per cubic foot of air. The response to the application of dry-air blast was prompt and efficient in result, and clearly demonstrated that, even at periods when the humidity of the atmosphere was relatively low, substantial economy in fuel could be obtained.

* January 1–10 only.

As already pointed out, an important advantage obtains by keeping the moisture in the air more uniform. Although the atmosphere is much more humid in the summer than in the winter months, yet in the latter the percentage of variation is much greater. A comparison of the average humidity of the several months of the year is misleading as to the effect of such humidity on the operations of a furnace, since such average results do not take into account the wide fluctuations from day to day, and even in the same day. During the past winter in the Pittsburg district, and generally throughout the northern states, there has prevailed a protracted cold season, and since the beginning of our observations there has been no winter season showing a lower average of humidity than the one just ended; therefore any demonstration under these conditions of the efficiency of dry-air blast in comparison with a furnace using normal blast is made at a time when the furnace operated with normal blast is at its highest efficiency.

It has been thought by some that the use of dry-air blast might be dispensed with in the winter months, when the content of moisture in the atmosphere is very low. There could scarcely be a month more favorable to the study of the effect of dry air than that presented in the month of February, 1905, where the average of moisture is 1.19 grains for the daytime and 1.17 grains for the night, with a maximum variation of 0.30 to 2.57 grains of moisture per cubic foot of air. In Table IV is shown the record for that month, and it will be noted that during several days the average moisture content of the atmosphere is lower than the average for the month in the dry blast.

As already pointed out the benefits derivable from the use of dry air can be directed in the main to increase of production, or to decrease in coke consumption, or to both purposes. In the month of February, by reason of the dry atmosphere and the large volume of air on No. 1 Furnace, the operations at No. 3 Furnace were directed principally toward economy in coke. The output on No. 3 is less than No. 1 Furnace, as the former was stopped several times during the month on account of breakdowns of slag machine and breakouts of iron at the hearth. Notwithstanding the low content of moisture in the normal blast, representing conditions rarely obtained in that district, the furnace supplied with dry blast made, considering the stops, prac-

TABLE IV.—*February.*

Date.	Grains of Moisture.				Temperature.				Gas Analysis.	
	In Atmosphere.		In Dry Blast.		Atmosphere.		Dry Blast.		CO.	CO_2.
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.		
Feb. 1	1·33	0·73	0·71	0·47	30	21	10	7	23·6	13·4
,, 2	0·39	0·30	0·35	0·18	13	7	3	−1	...	...
,, 3	0·48	0·39	0·31	0·22	9	9	1	1	23·8	13·4
,, 4	0·58	0·49	0·39	0·28	16	14	3	4	...	.
,, 5	0·73	1·64	0·41	0·63	20	31	6	11	...	...
,, 6	1·66	0·79	0·71	0·49	34	23	13	7	24·0	13·0
,, 7	0·69	0·67	0·51	0·35	23	16	7	3	...	..
,, 8	0·79	2·27	0·42	0·80	26	39	4	14	24·6	14·0
,, 9	2·57	1·67	0·95	0·78	43	37	16	13	23·4	14·0
,, 10	1·02	0·61	0·83	0·46	30	20	13	17	..	...
,, 11	0·60	1·04	0·56	0·52	18	30	6	9	...	...
,, 12	2·25	2·01	0·87	0·81	37	37	12	13	...	...
,, 13	0·72	0·40	0·64	0·28	20	9	9	2	24·6	13·4
,, 14	0·40	0·71	0·37	0·35	8	21	0	5	...	...
,, 15	0·45	0·32	0·48	0·24	16	9	3	2	...	...
,, 16	0·53	0·73	0·35	0·33	15	27	2	4	23·6	12·2
,, 17	1·04	0·84	0·61	0·48	33	27	9	6	24·0	14·2
,, 18	0·73	0·68	0·55	0·39	25	24	6	4	...	...
,, 19	0·87	1·15	0·51	0·60	27	32	5	9	...	...
,, 20	1·98	2·06	0·86	0·97	39	41	12	13	...	...
,, 21	1·56	2·11	0·71	0·88	38	37	14	10	25·6	12·4
,, 22	2·37	2·01	1·02	0·86	40	38	12	10	...	...
,, 23	1·86	1·69	1·11	0·74	28	36	13	9	24·0	14·0
,, 24	1·70	1·65	0·88	0·70	37	32	9	8	22·0	15·0
,, 25	1·77	2·10	0·91	0·88	34	40	10	10	...	...
,, 26	1·48	0·91	0·90	0·43	38	28	13	5	.	...
,, 27	0·97	1·34	0·70	0·53	29	35	8	10	...	...
,, 28	1·74	1·40	0·62	0·59	40	37	8	7	25·6	12·2
Average	1·19	1·17	0·65	0·54	28	27	8	8	23·9	13·4

The record of operations is as follows:—

	Average Daily Product.	Average Coke Consumption.	Blowing-Engines. Revolutions per Minute.	Average Temperature. Hot Blast.
	Tons.	Lbs.		Deg.
No. 1 Furnace (Normal Blast)	424	2248	111	800
No. 3 Furnace (Dry Blast)	412	1815	96	784

tically as much iron — with a consumption of coke 433 pounds less per ton of iron — as the furnace supplied with normal blast. As the summer season approaches, the product of the furnace using normal blast will steadily decrease and the fuel increase, while the work of the furnace supplied with dry air will continue practically uniform. It is doubtful if a better illustration can be had than that offered by the month of February in demonstrating the value of maintaining the blast practically uniform as to dryness.

As will be seen by Table V the advent of the spring months makes a material increase in the moisture. The operations in March were seriously interrupted by reason of high water in the Allegheny River, which flooded the works, and caused a shut-down of several days. On account of this shut-down extra charges of fuel were added to both furnaces. On starting the plant, No. 3 Furnace, supplied with dry air, responded more quickly and reached the normal grade of iron in one day, while it required three days to obtain like result on No. 1 Furnace The record for the month is set forth in Table V.

The product on No. 3 Furnace is a little less than on No. 1 Furnace, but No. 3 was banked nearly one day longer than No. 1, which would more than make up the difference.

In the discussion on my paper presented to the Institute in October, 1904, I note a comparison of the Isabella with the Edgar Thomson furnaces, without due regard being given to the different conditions existing at these plants. During the period covered in this communication the Edgar Thomson furnaces worked with a mixture of ores yielding 55.5 per cent of iron, while the Isabella mixture yielded but 51.5 per cent of iron, and, in addition, the stoves at the Edgar Thomson gave a temperature of from 200° to 300° higher than at the Isabella. The results achieved by the use of dry blast have been from furnaces that might properly be designated as old furnaces; they have been banked several times, which invariably has a deteriorating effect, and the coke used was an inferior grade from the Connellsville region, and used altogether on furnaces making basic iron.

The data presented in this communication are the furnace records entire for the points covered, and in considering them it is important to bear in mind that comparisons made with the

TABLE V.—*March.*

Date.	Grains of Moisture.				Temperature.				Gas Analysis.	
	In Atmosphere.		In Dry Blast.		Atmosphere.		Dry Blast.		CO.	CO_2.
	Day.	Night.	Day.	Night.	Day.	Night.	Day.	Night.		
Mar. 1	1·77	0·78	0·90	0·52	37	27	13	5	..	...
,, 2	0·78	1·00	0·55	0·44	29	30	4	7	...	...
,, 3	1·81	2·06	0·74	0·59	37	42	9	10	...	...
,, 4	1·98	1·16	0·91	0·42	44	31	13	8	...	...
,, 5	1·60	1·69	0·74	0·69	39	40	11	12	...	...
,, 6	1·24	1·44	0·75	0·62	38	38	10	10	23·5	14·0
,, 7	2·28	3·29	0·90	1·04	41	47	13	14	...	..
,, 8	2·73	1·61	1·07	0·68	44	33	15	9	..	...
,, 9	1·73	2·19	0·68	0·83	35	41	9	12	...	...
,, 10	1·94	1·20	0·88	0·60	43	32	14	10	...	...
,, 11	1·37	1·52	0·75	0·75	39	36	12	11	...	...
,, 12	1·33	1·09	0·74	0·54	40	32	11	9	...	...
,, 13	1·00	1·16	0·71	0·64	35	34	10	12	..	...
,, 14	1·22	1·32	0·81	0·57	36	33	12	10	...	...
,, 15	1·64	1·85	0·85	0·84	39	38	10	13	..	...
,, 16	2·47	2·74	1·11	1·12	49	52	15	18	...	...
,, 17	2·64	2·74	1·21	1·12	54	53	18	18	23·9	13·5
,, 18	2·85	3·84	1·31	1·38	64	65	21	24	...	...
,, 19	4·80	4·08	1·65	1·54	60	61	24	23	...	...
,, 20	Furnace banked on account of high water.									
,, 21										
,, 22										
,, 23	2·61	2·95	0·81	1·08	52	56	10	15	...	..
,, 24	3·32	3·08	1·32	1·15	58	51	21	16	...	..
,, 25	2·69	2·73	1·29	1·09	60	54	18	16	...	...
,, 26	3·19	2·93	1·20	1·11	58	58	17	16	...	...
,, 27	2·34	2·58	1·26	1·19	64	64	18	17	..	...
,, 28	2·92	4·04	1·29	1·42	66	63	18	23	...	...
,, 29	3·08	3·16	1·34	1·27	68	68	21	23	...	...
,, 30	3·30	2·18	1·42	0·88	59	49	22	16	...	..
,, 31	2·23	2·39	1·21	1·01	57	55	17	15	..	...
Average	2·25	2·25	1·01	0·89	48	45	14	14	23·7	13·7

The record of operations for the month are as follows:—

	Average Daily Product.	Average Coke Consumption.	Blowing-Engines. Revolutions per Minute.	Average Temperature. Hot Blast.
No. 1 Furnace— Normal Blast	Tons. 411	Lbs. 2274	111	Deg. 850
No. 3 Furnace— Dry Blast	405	1837	96	784

dry blast are under atmospheric conditions when furnaces operated with normal blast are doing their best work.

The writer takes this opportunity to state that in the diagrams in the former paper the record of each day is averaged with the preceding days.

NOTE ON THE FAILURE OF AN IRON PLATE THROUGH "FATIGUE" *

By SIDNEY A. HOUGHTON

Assoc. M. Inst. C. E. (London)

ALTHOUGH the consideration of the failure of metals by what is commonly called "fatigue" has engaged the attention of many experimenters, yet comparatively little has been written on the causes which ultimately produce fracture. Mr. Thomas Andrews in a series of articles published in "Engineering" in 1897–1898 appears to believe that failures of this description in steel are produced by weakening the joints of the crystals accelerated or induced by cracks arising from the minute flaws which exist in all commercial steels, but this theory is one which has not met with general acceptance. More recently Prof. J. A. Ewing and Mr. J. C. W. Humfrey have given in a very able paper,† the results of repeated alternations of stress on the structure of Swedish iron, and they express the opinion that fracture is due to constant slipping in the crystals, which ultimately produces cracks in their cleavage planes. With these two exceptions little or nothing seems to



* Iron and Steel Institute, May, 1905, meeting.

† "Philosophical Transactions," Vol. CC.

have been written as to the causes of fracture under fatigue stresses, and although it might be thought that with the advent of microscopical examination it would be a simple matter to ascertain their effect, yet, with mild steel, at any rate, considerable difficulty is experienced owing to the great purity and ductility of the ferrite crystals, which do not readily show the effect of small strains. Possibly it may be due to this cause that the literature on this important subject is so scanty.

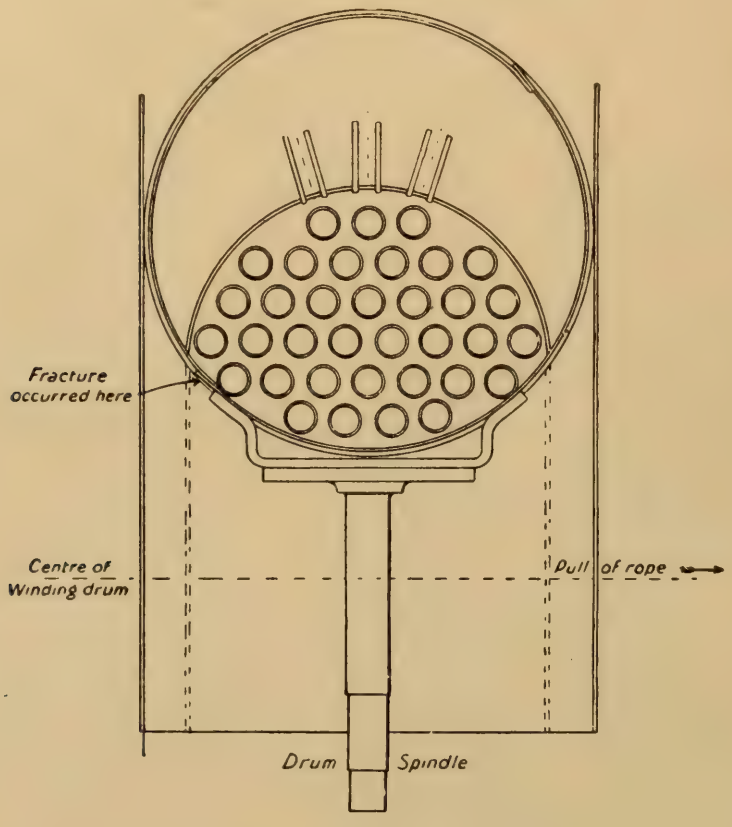


FIG. 1. Sectional Elevation through Back Ring of Barrel of Boiler

In the case about to be described, although the plate was of iron, its quality differed very materially from that used by Professor Ewing, and for that reason, and as it occurred in actual practice, a consideration of it may be of some value.

The plate which failed was in the back ring of the barrel of a portable boiler of the locomotive type, which formed part of a steam plowing engine. As a rule barrel plates are not subjected to fatigue stresses of importance, but in this instance the

step or bracket which carried the spindle of the winding drum was riveted to it (Fig. 1), and consequently when plowing was being done the plate was subjected to severe panting stresses. These would be in addition to the tensile stress due to the pressure of steam, which would theoretically amount to 3.67 tons per square inch between the rivet holes, and 2.17 in the solid plate when new; but owing to wasting, these figures would have increased to 5.71 and 3.38 when fracture occurred. It must also be noted that the iron was thus stressed when at a temperature of about 350° F., when its ductility would be less than when cold. Moreover, as one end of the step was riveted close to a longitudinal lap joint, the fatigue stresses were to a great extent localized, and failure actually occurred through a crack forming between the rivet holes. Unfortunately this crack began from inside the outer lap of the plate, and consequently was not discovered, the result being that the boiler exploded with great violence and instantaneously killed a man who was near.

The boiler was about twenty years old, but as plowing is only done during part of the year the actual time it was at work may be considered as about six years. The barrel plates were originally about 7-16 inch thick, but had wasted externally to 9-32 inch near the joint which gave way, consequently the stresses at this part must have gradually increased in severity. These plates were made of B. B. iron, the actual analysis being: carbon, trace; manganese, trace; sulphur, 0.023; phosphorus, 0.310; silicon, 0.180 per cent, from which it will be seen that the phosphorus is high and the silicon more than usual.

A tensile test cut lengthways of the plate near the fracture gave 23.8 tons per square inch with only 2 per cent elongation in $1\frac{1}{2}$ inches, the last result being to some extent influenced by a small flaw near the middle. The fracture was coarse crystalline. The metal was distinctly hard, and although inferior considered as iron, its very want of ductility rendered it specially suitable for studying the effects of fatigue. Several sections were cut from the plate in three planes, and the structure, which was fairly similar in all the longitudinal sections, showed, as might be expected, large ferrite crystals with a considerable quantity of slag flaws, the slag itself frequently showing a duplex structure. Many of the crystals exhibited very clearly that wavy eutectic appearance which seems to be characteristic of commercial

wrought iron containing phosphorus, and to which attention has already been directed.*

The rivet holes had been punched, and notwithstanding this was done twenty years ago, the effect on the structure in distorting the neighboring crystals was apparently as clear as if the plate had just come from the machine. Although failure took place between the rivet holes, numerous small cracks parallel to the line of fracture had formed on the inside of the plate in the vicinity, and it was one of these which, as previously remarked, reduced the elongation in the tensile test. A fairly typical example is shown in Fig. 2, which is a photomicrograph of the plate about $\frac{1}{2}$ inch from the line of fracture, the top of the photograph being the inside surface of the plate. The crack begins at the surface, where it is fairly straight, but it is probable that this part is influenced by pitting action. A small portion of the crack appears to the left, but the main part is near the center of the photograph. Although the different parts appear disconnected, it must be remembered that only a plane surface is shown, and it is probable that the gaps are due to these crystals possessing greater ductility or more suitable orientation to resist fracture, and that the cracks are really connected in other parts of less resistance.

The results of the action of the stresses on the structure of the metal may be summed up as follows:

Formation of slip lines, indicating slipping of the crystals.

Loosening of the joints between the crystals.

Loosening of the particles of slag.

The observance of slip bands in metal is, it is believed, due to Professor Ewing and Mr. Rosenhain, and they particularly call attention to their appearance in metal subjected to numerous reversals of stress. Their remarks are fully borne out by the metal under consideration, many very fine examples of these lines being visible in sections near the fracture (Fig. 2). It should, however, be observed that none were produced in the test piece when broken in the machine, and this is a somewhat remarkable fact. In addition to these lines many crystals showed signs of being strained in various directions, and some even appeared to be breaking up into small ones. An example of one of these is

* " The Internal Structure of Iron and Steel," by the author. " Proceedings " of the Institute of Marine Engineers, 1902, Vol. XIV.

shown in Fig. 2, where also may be seen some crystals with wavy marks.

The looseness at the crystalline joints is only slightly evident, and would be somewhat difficult to detect without com-



FIG. 2. Longitudinal Section of B. B. Iron Boiler Plate, showing crack produced by "fatigue." Magnified 53 diameters. Etched with picric acid.

parison with unstrained metal of the same description. The slag flaws do not seem to have extended appreciably, and the conclusions arrived at by Mr. Andrews are certainly not supported by the results of the examination of this plate, which,

however, are closely in accordance with the views enunciated by Professor Ewing; that is, that the real cause of failure is the fracture of the crystals along cleavage planes. The cracks, however, appear to start from small surface flaws which would naturally tend to concentrate the stresses, and it would seem, therefore, important to keep the surface of material subjected to these stresses as clean and smooth as possible. The cracks seem, perhaps, to follow the junction lines of the crystals to a rather greater extent than when metal is broken in a machine, and as might be expected the slag flaws influence their direction in a marked manner. Some years ago Mr. Stead called attention to the fact that probably these flaws helped to increase the resistance of wrought iron to cross-breaking, and this is supported by the course of the cracks in this metal. Briefly, the effect is to avoid the concentration of stresses in a single plane, and the resistance to fractures of this description is, therefore, considerably increased.

As observed, the plate had wasted considerably in the vicinity of the joint, and it appears probable that this wasting was to some extent due to the straining of the crystals. For when slipping occurs minute clean surfaces of iron would be exposed in close conjunction with the surface oxide, and consequently a rapid electrolytic action would arise. This theory may also explain the reason of grooving in boilers which occurs where the plates are locally stressed. It is true that Professor Bose has shown that when two similar pieces of metal are placed in an electrolyte and one is strained, an electric current passes, but it is suggested that the cause of this is due to the exposure of a fresh surface of metal and not to any undiscovered means for producing electric potential.

To sum up, the effect of fatigue stresses on this plate has been to form cracks commencing, as a rule, from irregularities on the inner surface, which cracks were due to weakness in the cleavage planes of the crystals from continual slipping, and to a less degree to some loss of adhesion between the crystals. Some of the crystals appear to have been broken up, and as regards the slag flaws these seem to have a restraining effect on the progress of the cracks.

It may be added that these remarks are not intended to have a general application, but are written in the hope that they may

lead to further and more comprehensive investigations being undertaken in this very important subject.

CHEMICAL CHANGES IN THE OPEN-HEARTH FURNACE *

By W. M. CARR

THE accompanying diagrams may be of interest in setting forth the changes of composition occurring in a bath of molten metal treated under normal conditions of regular open-hearth practice when producing steel to enter into ordinary castings. In both cases under investigation the initial chemical composition of the metals going into each charge was carefully calculated from numerous analyses of stock on record in the laboratories of the American Steel Foundries. The acid heat was a regular one turned out at the Chicago works. The basic heat was the regular product of the Granite City (Illinois) Works. The investigations were conducted in the early part of 1903 under the writer's direction as metallurgist of their Western district.

Of course the acid heat was composed of low phosphorus pig iron and basic steel scrap (billets, plate, defective basic steel castings and shop scrap). The final analysis of the heat was made from a sample taken when about half of the contents of the ladle had gone into castings. This, of course, gave a representative sample of the entire finished heat. Analyses made at other times to determine variations of constituents between the first and last portions of a normal ladleful of steel showed that for regular practice and purposes a sample taken in the middle of a pour was decidedly representative of the whole.

All samples taken during the investigation of this acid heat were regarded as an average at the several times. In following the manganese line it will be noticed that there is an increase of that element shortly after the metals are melted. This can be explained as the result of an addition of a moderate quantity of ferro-manganese during that period, the aim being to wash the bath. At the time of the investigation such a plan was regular practice in all heats at these works. The gradual increase in

* Received in February, 1905.

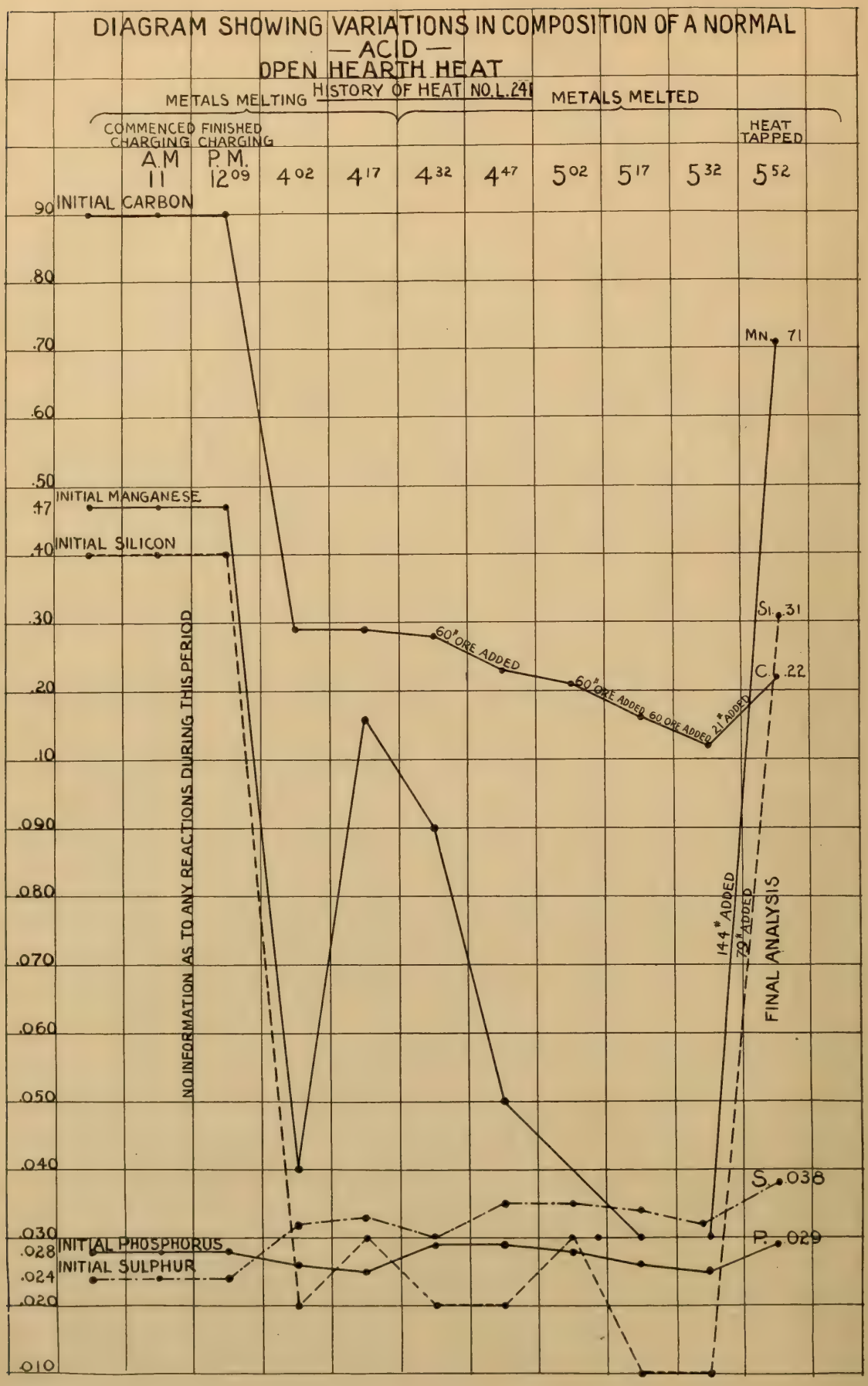
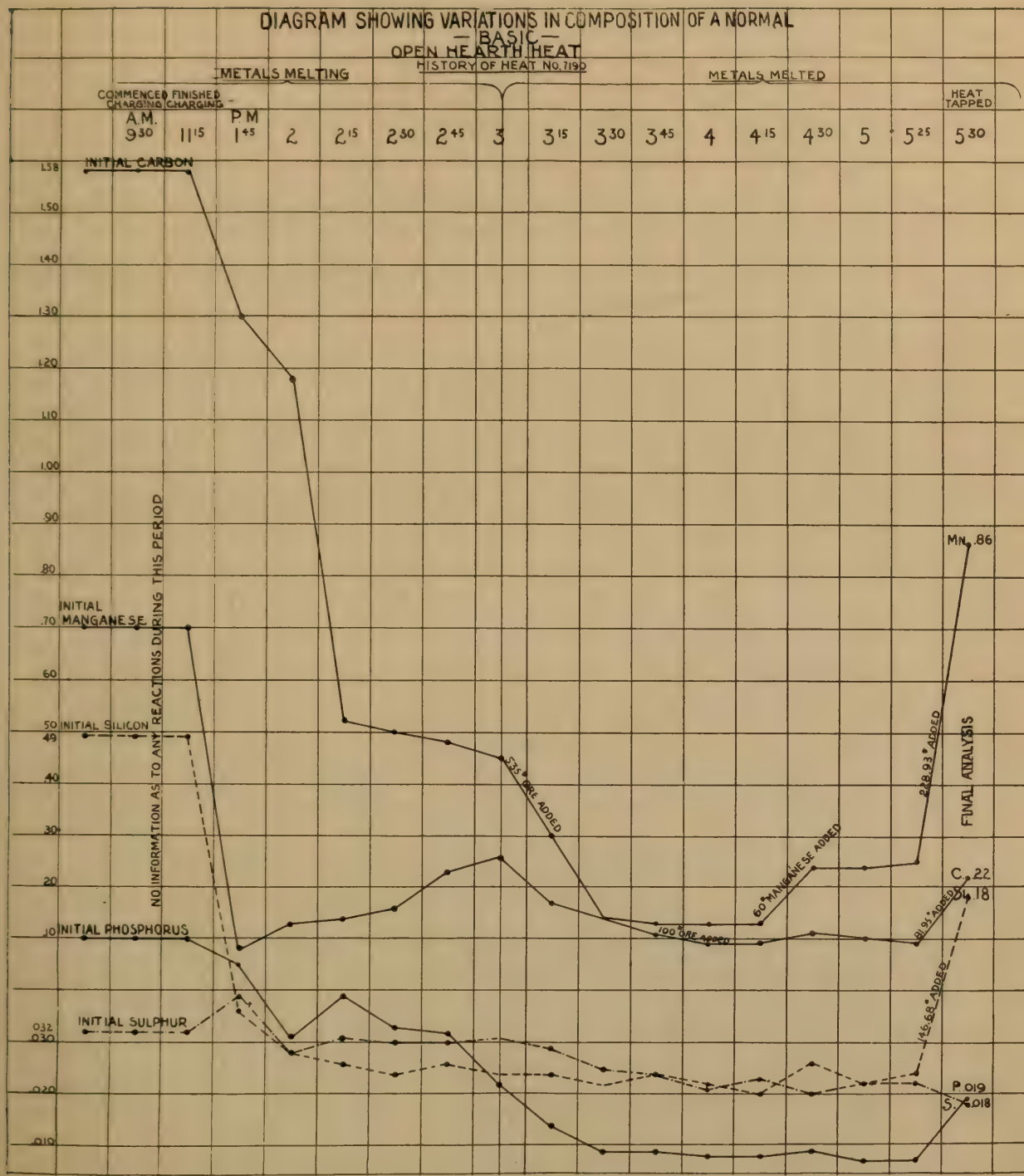

DIAGRAM SHOWING VARIATIONS IN COMPOSITION OF A NORMAL
— ACID —
OPEN HEARTH HEAT
HISTORY OF HEAT NO. L.24
METALS MELTING
METALS MELTED
COMMENCED CHARGING
FINISHED CHARGING
HEAT TAPPED
A.M 11
P.M. 12 09
4 02
4 17
4 32
4 47
5 02
5 17
5 32
5 52
INITIAL CARBON
INITIAL MANGANESE
INITIAL SILICON
INITIAL PHOSPHORUS
INITIAL SULPHUR
NO INFORMATION AS TO ANY REACTIONS DURING THIS PERIOD
60" ORE ADDED
60" ORE ADDED
60 ORE ADDED
21" ADDED
144" ADDED
72" ADDED
FINAL ANALYSIS
MN. 71
SI. 31
C. 22
S. 038
P. 029
90
80
70
60
50
47
40
30
20
10
090
080
070
060
050
040
030
028
024
020
010

DIAGRAM SHOWING VARIATIONS IN COMPOSITION OF A NORMAL
— BASIC —
OPEN HEARTH HEAT
HISTORY OF HEAT No. 7190



sulphur would be the result of two causes: First, in view of fuel oil as a source of heat it was supposed that there would be some absorption of sulphur from the flame while the metals were exposed to its action before the final liquefaction and disappearance below the slag and away from its direct influence. Second, the oxidizing action of the flame would mean some loss in metallic iron, and in the absence of any active basic absorbent there would be a corresponding increase of sulphur in the molten metal. The changes in phosphorus would be subject to the same conditions as the sulphur in the second stage (metals melted) plus the amounts carried in by the deoxidizing agents, *i. e.*, ferro-manganese and ferro-silicon.

In regard to the basic heat the conditions are, if anything, more interesting than in an acid heat, because of greater changes in composition following the purifying action of CaO furnished by a liberal charge of limestone. The pig iron of the charge consisted of two kinds of basic pig, one containing about 1 per cent phosphorus and the other about 2 per cent. The scrap was steel rails, defective steel castings and shop scrap. Therefore the initial phosphorus was not very high in the total charge of metals. Fuel oil was the source of heat in this case also. It cannot be said that the samples taken at regular intervals after the completion of the charge going into furnace and taken immediately upon the partial melting of the metals were representative ones. It was the practice to put in last a certain portion of the pig iron, and owing to its relative low melting point, the samples of metal taken during the first stage of the investigation (metals melting) would be those of molten pig iron more or less refined by whatever slag may have formed during the first step. The composition of the mass of metals of course would vary, depending upon whether one might reach, in taking a sample, a quantity of either molten pig iron or molten steel scrap. But after complete fusion and under the layer of rapidly forming slag it was quite safe to assume, in the gradual progression of the second stage (metals melted), that the samples would be a fair average of the bath. The changes in sulphur and phosphorus give plain evidence of slag action. It is noteworthy that the sulphur decreased rapidly near the end of the heat. This was thought to be due to the influence of manganese carried in by the ferro-manganese in the final working of the heat and the preliminary deoxidizing of the

bath before tapping. The change or increment of phosphorus was due to the influence of silicon carried in by ferro-silicon used also as a preliminary deoxidizing agent before tapping, as silicon would release phosphorus from the slag. The complete deoxidizing was done in the ladle while tapping with the assistance of ferro-manganese, ferro-silicon and carborundum. The weights of carbon shown to be carried in in the final additions were furnished by calculations of the available carbon in the several deoxidizing agents. The same applied to the manganese and silicon and also refers to the acid heat in the same particulars. The final analysis was determined on a sample taken about the middle of the pour while going into castings. This was regular practice and only represented the steel at that time. In basic steel for castings it is known that the composition varies in regard to phosphorus, it increasing towards the end, the cause being in the main due to a reabsorption of that element by the metal immediately below the slag. The amount absorbed varies greatly and depends upon many conditions. Therefore the final analysis of the basic heat was fairly representative of the whole, with the possible exception of the content of phosphorus.

COPPER ALLOYS *

SPECIAL BRASSES AND QUENCHING OF BRONZE

By L. GUILLET

Translated from the French for The Iron and Steel Magazine

(*Continued from page 509, Vol. IX*)

Tin Brass — Theoretical Study. Tin brasses have recently been much used in naval construction. No general study of this group of ternary alloys has yet been conducted, and in the present investigation it has been confined to the influence of tin upon ordinary brass containing 60 per cent copper and 40 per cent zinc.

It results from our microscopical study that tin plays the same part as zinc, but with a much greater activity, 1 per cent of tin being as effective as 4 per cent of zinc.

Among the accompanying photomicrographs (Figs. 16 to

*" Revue de Métallurgie," February, 1905.

19) we shall call attention to those representing an alloy with 54 per cent copper and 6 per cent tin and an alloy with 60 per cent copper and 10 per cent tin. The latter alloy has the same

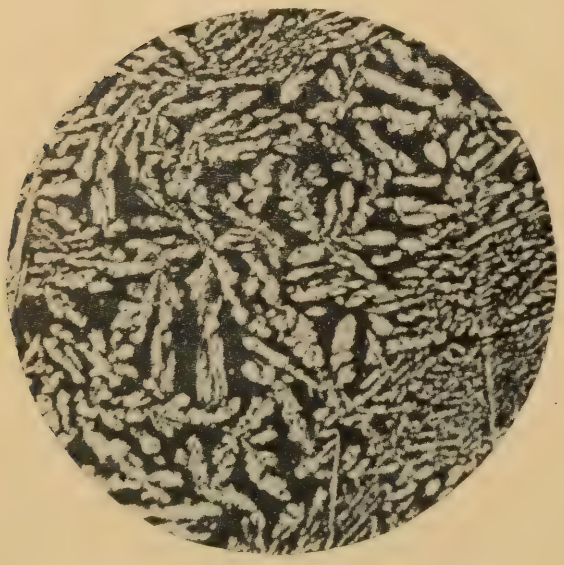


FIG. 16. Cu, 60%; Zn, 39.5%; Sn, 0.5%. Magnified 200 diam.



FIG. 17. Cu, 60%; Zn, 39%; Sn, 1%. Magnified 200 diam.

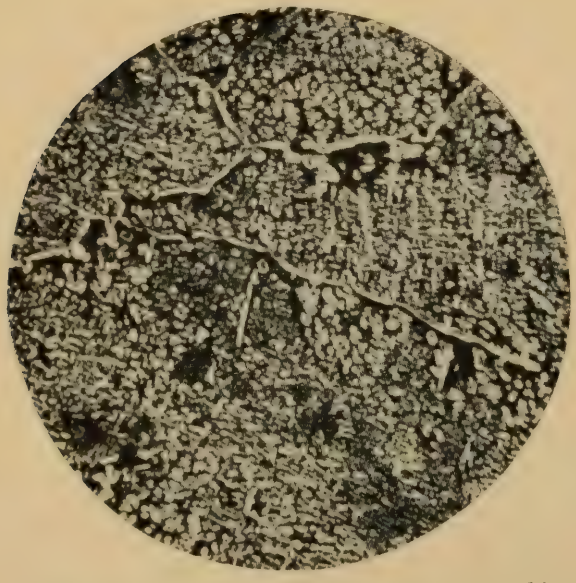


FIG. 18. Cu, 54%; Zn, 40%; Sn, 6%. Magnified 200 diam.



FIG. 19. Cu, 60%; Zn, 30%; Sn, 10%. Magnified 200 diam.

structure as the first one although it contains more copper and more tin. Their structure recalls that of a brass containing 55 per cent zinc.

Manufacture. — The production of these alloys does not call for any special care. Like lead, the tin is added when ready to cast, a short time before removing the crucible from the furnace.

Properties. — Brasses containing more than 4 per cent of tin can no longer be used, being extremely brittle and having a fracture exhibiting large grains and a silver-gray appearance. Diagram 4 shows graphically the results of the testing of some bars which were rolled, drawn and reheated.

These results show (1) that tin increases a little the tensile strength, (2) that it increases a little the elastic limit, (3) that it rapidly decreases the elongation and reduction as soon as it

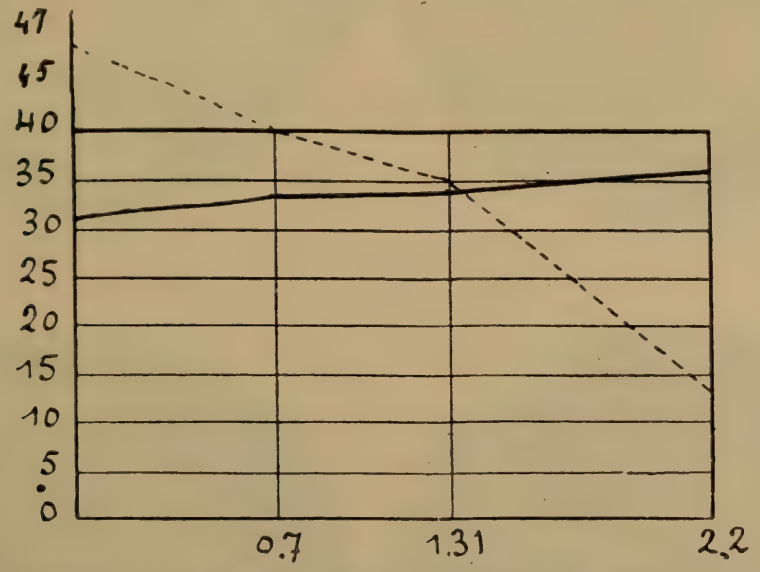


DIAGRAM 4. Tin Brass. Rolled, Drawn and Annealed Bars

exceeds 1 per cent, (4) that it produces a very marked brittleness and (5) that it increases the hardness. Their deduction agrees with the appearance of the microstructure of these alloys, and it follows that large proportions of tin should not be introduced in brasses. If the brass is to be worked hot, the tin content should not exceed 2.5 per cent.

An important property due to the introduction of tin has been shown by numerous experiments, that of greatly increased resistance to corrosion by sea water.

Uses. — The composition generally adopted for naval uses is as follows: copper, 60 to 62 per cent, tin 1 to 1.5 per cent and zinc 39 to 37 per cent.

Tin is also utilized in most brasses of great strength in which it is present in amounts varying between .3 and 1.5 per cent.

Manganese Brass. — Theoretical Study. Mr. Guillemin has



FIG. 20. Cu, 59%; Zn, 40%; Mn, 1%. Magnified 50 diam.

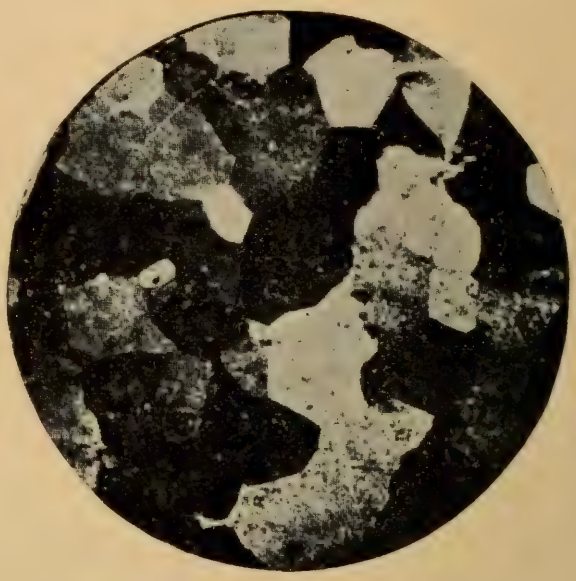


FIG. 21. Cu, 54%; Zn, 40%; Mn, 6%. Magnified 50 diam.

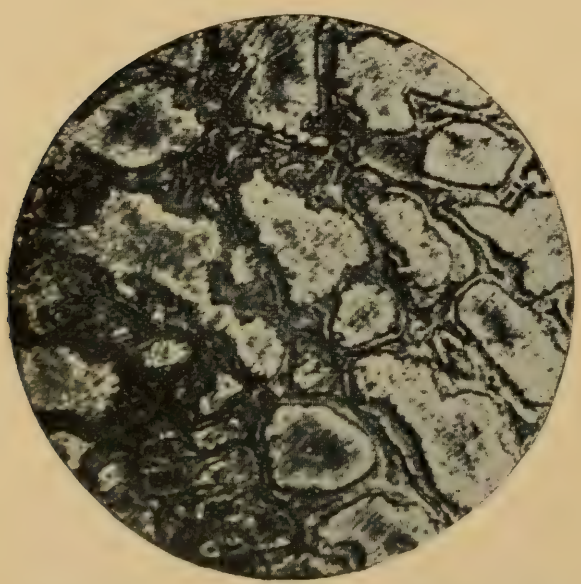


FIG. 22. Cu, 65%; Zn, 30%; Mn, 5%. Magnified 200 diam.

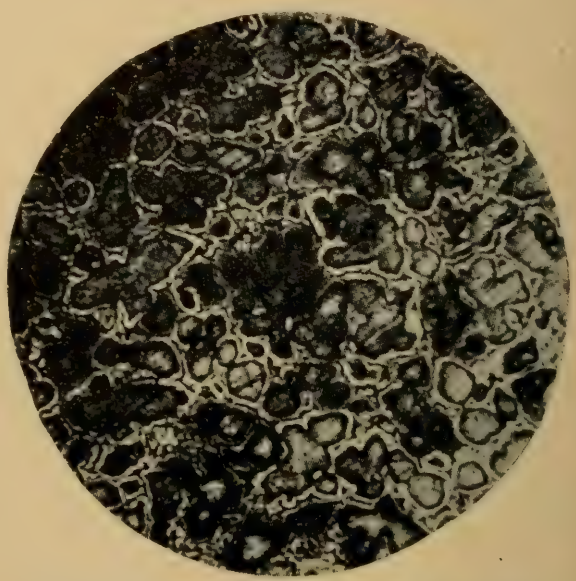


FIG. 23. Cu, 60%; Zn, 30%; Mn, 10%. Magnified 200 diam.

published several photomicrographs of manganese brass. Although he does not indicate the chemical composition of these alloys, the microstructure of ordinary brass is easily recognized,

as further shown in Figs. 20 to 23. It will suffice to note the structure of the brass containing 54 per cent copper and 5 per cent. manganese and to compare it with that of an ordinary brass containing 54 per cent copper and 46 per cent zinc. It would seem, therefore, that manganese merely takes the place of zinc, producing a similar effect. The results shown in diagram 5 were obtained by testing bars of brass containing originally 54 per cent copper and 46 per cent zinc and in which some of the copper was replaced by manganese.

To confirm these results two alloys were examined contain-

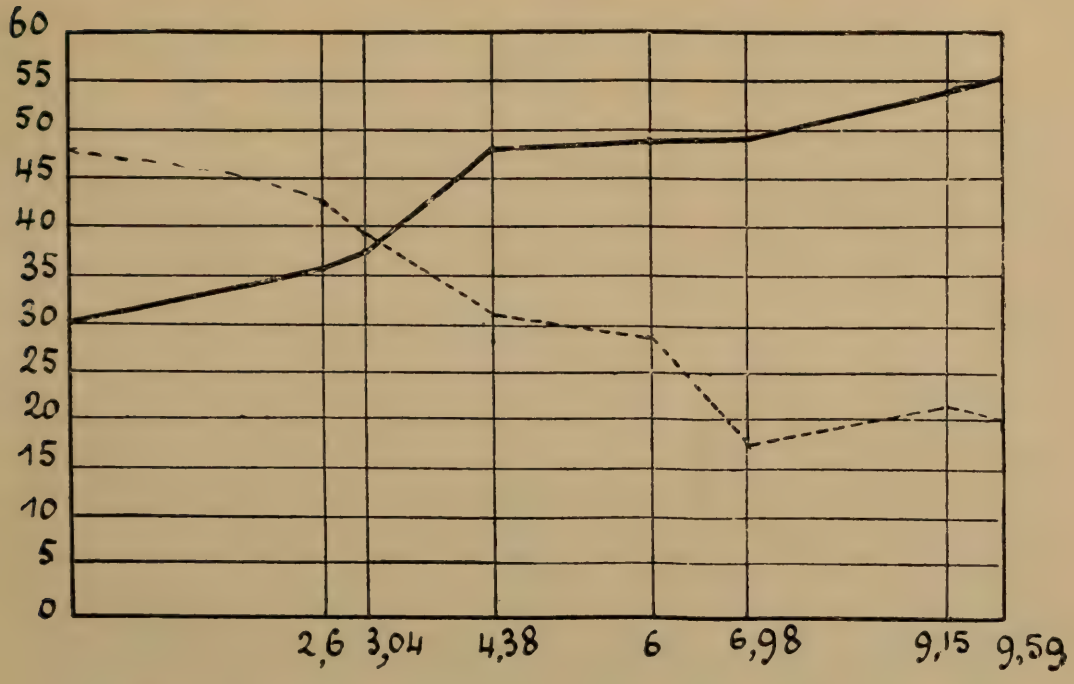


DIAGRAM 5. Manganese Brasses. Rolled, Drawn and Annealed Bars

ing (1) 45 per cent copper, 10 per cent manganese and 45 per cent zinc, and (2) 55 per cent copper and 45 per cent zinc. They were found to have respectively the same structure as brass containing (1) 45 per cent copper and 55 per cent zinc and (2) 55 per cent copper and 45 per cent zinc.

Manufacture. — The first samples of manganese brass were obtained by Stirling and Parker, who reduced some oxide of manganese by means of carbon in presence of copper and followed by the addition of zinc. In 1876 Parsons, who was the first to study these alloys, added to the copper some ferro-

manganese and utilized the resulting ferro-cupro-manganese for the preparation of manganese brass and manganese bronze. At

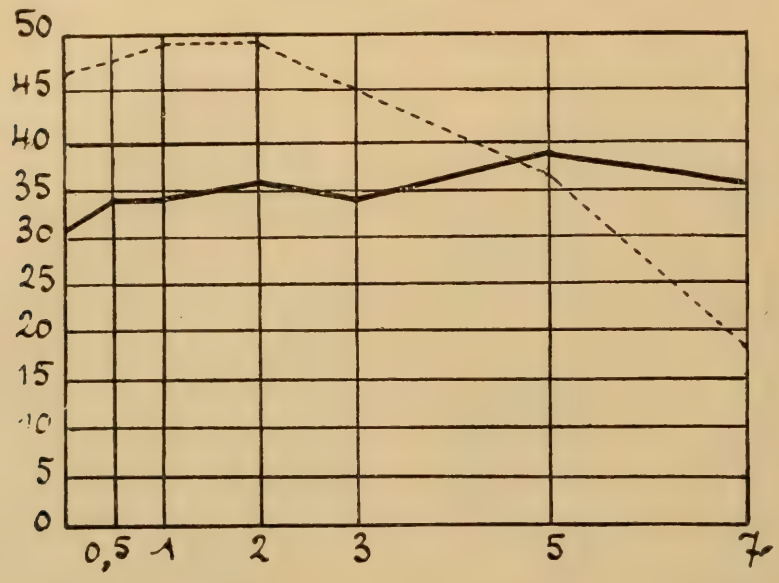


DIAGRAM 6. Manganese Brass. First Type, Cast Bars

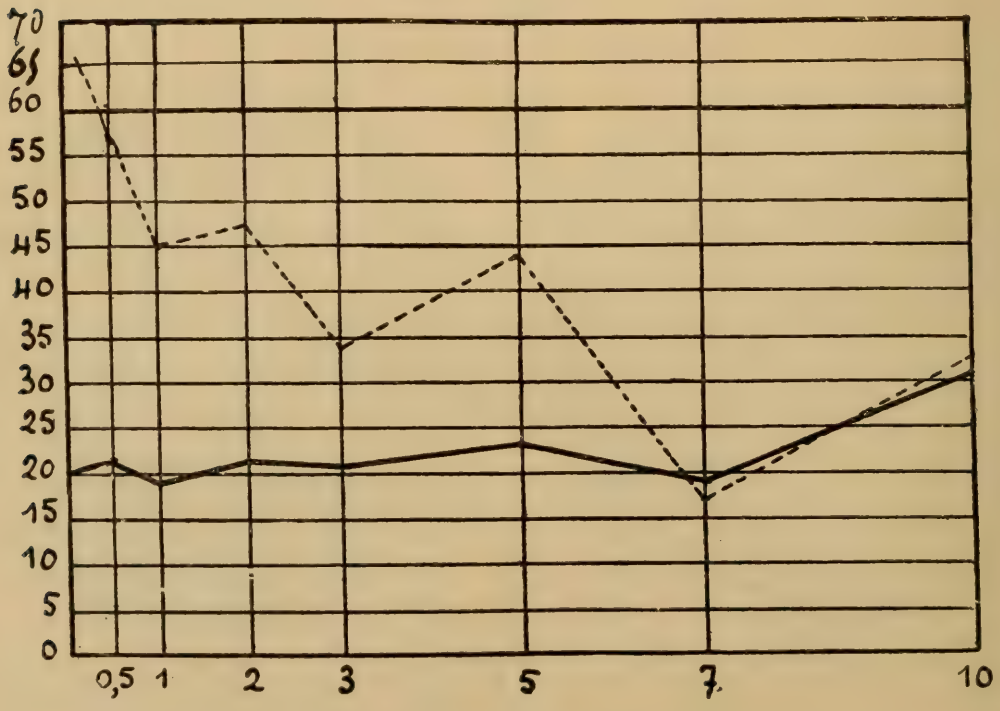


DIAGRAM 7. Manganese Brass. Second Type, Cast Bars

present cupro-manganese, an alloy of copper and manganese, is universally employed. It is added in suitable proportions a

short time before casting. If a large amount of cupro-manganese is to be used, most of it should be melted in the crucible itself, but a little should be kept to be thrown into the crucible when ready to cast. It should be borne in mind that manganese may play in the manufacture of brass (as in that of bronze) a double part: (1) it is a deoxidizer which will reduce the oxides present in the bath* and (2) it confers, when present in excess, special physical properties as shown below.

Mechanical Properties. — The results obtained by the testing (1) of cast bars and (2) of bars which were rolled, drawn and reheated, are shown in diagrams 5, 6 and 7.

The following results were moreover obtained by Mr. Guillemin, with some manganese bronzes:

Description	Treatment	Tensile Strength tons per sq. mm.	Elongation %	Reduction %
Soft Mn bronze	Cast in sand at 1200° C.	36	14	30
„	Cast in sand at 1250° C.	34	13	35
„	Cast in sand at 1300° C.	31	12	45
„	Cast in sand at 1400° C.	24	9	13
Medium hard Mn bronze (Roma)	Cast in sand at 1250° C.	37	17	25
Hard Mn bronze (Roma)	Cast in sand	40	20	18
Very hard Mn bronze (Roma)	Cast in sand at 1250° C.	45	24	15
Medium hard Mn bronze	Hot rolled and annealed	45	18	30
Medium hard Mn bronze (Roma)	Hot rolled, stamped and annealed	56	30	25
Hard ferro Mn bronze	Cast in sand	36	17	10

From these numerous tests the following inferences may be drawn regarding the effect of manganese:

1. It increases decidedly the tensile strength.

* This effect, however, is open to discussion, especially in the case of bronze.

2. It increases the elastic limit.

3. At first it increases and then decreases the elongation and reduction. This increase of elongation produced by a small amount of manganese is not evident in the case of rolled bars because a large amount of manganese was at once added.

4. It increases the brittleness but only when it exceeds 4 per cent.

5. It increases the hardness very slowly.

In Mr. Guillemin's experiments the temperatures were measured by means of a Ducreted optical pyrometer.

In the case of rolled or forged bars, which are extensively used in the arts, manufacturers are generally able to guarantee the following properties:

	Tensile Strength	Elastic Limit	Elongation
Castings	35 to 40 kg.	15 to 20 kg.	15 to 25%
Drawn bars	40 to 50 kg.	20 to 30 kg.	15 to 25%
Forged parts	40 to 45 kg.	20 to 25 kg.	20 to 30%
Rolled sheets	38 to 45 kg.	15 to 20 kg.	18 to 25%
Fine wire	up to 105 kg.	85 kg.	25%

The properties of drawn or forged bars depend primarily on the amount of cold work they have received and this is, of course, also the case with wires.

Some weldless tubes are manufactured of manganese brass which have a tensile strength of 45 to 60 kg. per square millimeter, an elongation of 20 to 40 per cent and a reduction of 15 to 25 per cent. The following two types of manganese brass are most employed:

1. Cu, 59 to 60 per cent; Mn, traces to 1 per cent; Zn, 41 to 40 per cent.

2. Cu, 58 to 59 per cent; Mn, 1.8 to 2.2 per cent; Zn, 40 to 39 per cent.

It should be added that brasses containing manganese only are not those that are most used.

The Manganese Bronze and Brass Company has obtained the following results in comparing the hardness of some metals to that of ordinary manganese bronze and to that of manganese bronze cast under pressure. The test consisted in producing the same indentation by means of a knife, the pressures required being taken as a measure of the hardness.

	Pressure
Gun metal	12
Wrought iron	15
Soft steel	20
Soft steel quenched in oil	25
Manganese bronze	20
Manganese bronze hardened by pressure	22 to 23

From these results the Manganese Bronze and Brass Company recommends the use of these alloys for parts of machinery which must resist high internal pressure, such, for instance, as hydraulic cylinders and others.

It is well to remember that manganese brasses are generally sold as manganese bronzes, although they frequently contain little or no tin.

(*To be concluded*)

METALLOGRAPHY APPLIED TO FOUNDRY WORK*

PART II

By ALBERT SAUVEUR

Development of the Structure of Polished Samples of Cast Iron

WHEN samples of gray cast iron, polished as described in the first installment of this article, are examined through the microscope, numerous small, irregular cavities are revealed which mark the spaces once occupied by the small particles of graphitic carbon always present in this grade of iron. Most of these graphite particles are removed by the polishing operation, but the small cavities which remain indicate accurately their former location and shape. Fig. 1 shows under a magnification of 56 diameters the appearance of a sample of gray cast iron after polishing. The irregular cavities just referred to, whether they still contain their graphite or not, appear as so many black areas. It will readily be inferred that the appearance of the magnified image of this polished sample of gray cast iron should convey at least as much information concerning the physical and chemical characteristics as the examination of the fracture; or, in other words, that these properties must be closely related to

* "The Foundry," June, 1905.

the number of the graphite particles revealed by polishing, to their size and shape, their distribution, etc. I shall have occasion to show that very valuable information may indeed be obtained from the microscopical examination of polished samples of cast iron without subjecting them to further treatment, but it will be noted that in these samples the structure of the metallic part is not revealed. The polishing operation has imparted the same appearance to the various constituents of which this metallic mass is composed; they have all assumed a mirror-like aspect, reflecting the light to the same extent, so that it is not possible to distinguish them from each other. In order to make these various constituents visible under the microscope it is necessary

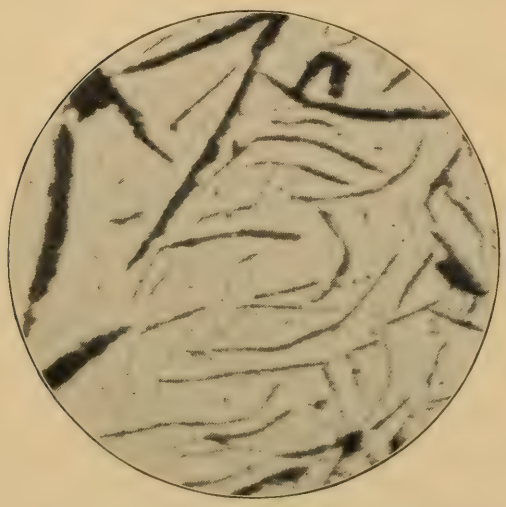


FIG. 1. Gray Cast Iron, polished but not etched. Magnified 56 diameters.



FIG. 2. White Cast Iron, polished in relief. Magnified 100 diameters.

to impart to them unlike appearances through the action of certain treatments affecting them differently. These treatments generally consist in subjecting the polished samples to the action of acids or of some other reagents which attack certain constituents to the exclusion of others or with varying degrees of intensity; they are generally known as " etching treatments."

Polishing in Relief. — In the case of white cast iron two constituents are present (to be described later) which differ much in hardness, and if the tripoli and rouge polishing be continued for a sufficiently long time, and especially if it be conducted on a soft, yielding backing, a pronounced relief effect is produced resulting from the greater wearing of the soft constituent. The

difference in level of the two constituents obtained in this way differentiate them under the microscope without further treatment.

Fig. 2 shows the microstructure, magnified 100 diameters, of a sample of white cast iron polished in relief. The presence of two constituents is clearly brought out. The soft constituent appears dark because, being somewhat depressed, each particle of it pertains, microscopically speaking, of the nature of a shallow cavity. The differentiation is further assisted by the soft constituent assuming a mottled appearance, while the hard component retains its specular aspect.

While such relief polishing makes it possible in the case of white cast iron to observe some features of the structure without further treatment, and while it is occasionally valuable, it seldom reveals structural details which are not better brought out by an etching or some other developing treatment.

Etching Methods. — Many reagents have been recommended for etching polished samples of iron and steel, but I shall only describe here those treatments which, so far as my experience goes, yield the best results.

The structure of cast iron may be made apparent by etching polished samples with one of the following solutions: (1) Nitric acid in absolute alcohol, (2) picric acid in absolute alcohol, (3) concentrated nitric acid and (4) tincture of iodine. I have named them in the order of my preference.

Etching with a Solution of Nitric Acid in Alcohol. — A solution should be prepared containing 10 per cent of concentrated nitric acid (1.42 sp. gr.) and 90 per cent of absolute alcohol. A small amount of this solution should be poured in a small beaker or dish and the polished sample immersed in it for a very short time (seldom exceeding 10 seconds). It is generally better not to leave the sample in the solution for more than five seconds and to repeat the treatment if it be found that the etching was too slight. When the sample is taken from the etching bath, it should be quickly washed in alcohol and carefully dried, preferably by means of an air blast, followed by gentle wiping with a soft cloth; or, lacking a blast, altogether with a soft cloth.

A piece of chamois leather may also be used to advantage for wiping the specimen, after drying it, immediately before examining it under the microscope. To that effect it is con-

venient to nail a small piece of the leather on a piece of wood and to rub the specimen over it once or twice. This block should be kept carefully covered to prevent any dust from settling upon it.

The etched specimen is now ready for microscopical examination.

Etching with a Solution of Picric Acid in Alcohol. — A solution should be prepared containing 10 per cent of picric acid and 90 per cent of absolute alcohol and the etching conducted exactly as described for the treatment with nitric acid in alcohol.

Etching with Concentrated Nitric Acid. — The polished samples should be dipped in concentrated nitric acid (1.42 sp. gr.) and immediately held under an abundant stream of running water. When iron is immersed in concentrated nitric acid it assumes what is known as the passive state, *i. e.*, it is not affected by the acid. As soon as the layer of concentrated acid which covers the polished surface, however, is diluted by the running water, it attacks the iron vigorously, but for such a short time (since the water soon removes all traces of acid) that there is very little danger of etching too deeply. One such treatment is generally sufficient to bring out the structure sharply and clearly, but if the sample be found insufficiently etched the etching should be repeated in exactly the same manner.

Etching with Tincture of Iodine. — Some tincture of iodine, such as may be obtained from pharmacists, should be diluted with the same amount of alcohol. A little of this solution should be applied to the polished surface, conveniently, by dipping a finger's end in the tincture and gently rubbing the specimen and repeating the treatment until the surface appears dull or slightly tarnished. The sample should then be washed in alcohol and dried.

Heat Tinting Method. — This method consists in heating the polished sample gently and gradually in contact with the atmosphere, by holding it over a Bunsen flame, for instance, or placing it on a hot plate or in some other suitable manner. The different constituents assume, in rapid succession, but with varying velocities, different shades due to the formation of light films of oxides, in such a way that at no instant of the heating are two components colored alike. This method has been applied extensively and with much success to cast iron by Mr. J. E. Stead, and I shall have occasion to again refer to it.

A NEW HARDENING FURNACE

THE half-tones, Figs. 1 and 2, illustrate a new hardening furnace invented by S. N. Brayshaw, of Manchester, England, and which makes use of a salt bath for heating the work,* special provision being made for controlling the temperature of

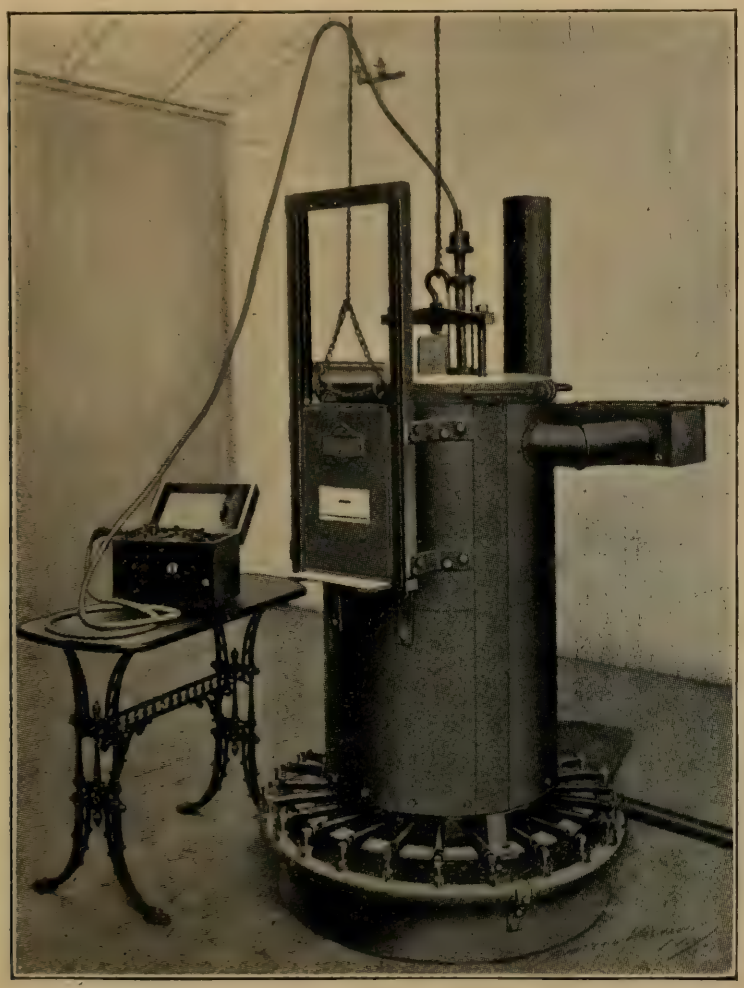


FIG. 1. Hardening Furnace

the bath as well as the whole interior of the furnace and for handling the material to be hardened.

The inventor's contention is that the treatment of steel cannot be accurately regulated in an open furnace, and that it

* "American Machinist," March 16, 1905.

is necessary to immerse the steel in a liquid to be sure of its temperature to within a few degrees. Having experimented extensively with lead, he considers that a salt bath is better, and has brought out a special preparation to be used as a bath in this furnace. The operation of the latter is based upon the laws controlling the heating and cooling of steel, and in this connection two heating and cooling curves taken by Mr. Brayshaw are of interest: One of these curves, Fig. 3, marked "S. & D. Best Cast Steel," is for ordinary carbon steel, and has been taken by drilling a hole into the piece of steel and inserting the pyrometer into this hole, the wires of the pyrometer being connected with the self-recording indicator. The piece of steel is then heated slowly and uniformly in an electric furnace. During the period of heating there is an arrest in temperature at about the point 726° C. This arrest in temperature always occurs at the same point for the same steel. Of course it is understood that although the temperature is not rising at this point the steel is absorbing heat from the furnace at a uniform rate all the time. After the absorption is complete the temperature again rises regularly as before. After the temperature has risen for some time the current is switched off and the steel is allowed to cool with the furnace. After cooling with a fair degree of uniformity for some time, it will be observed that the fall in temperature of the steel ceases, although the cooling of the furnace and of the steel

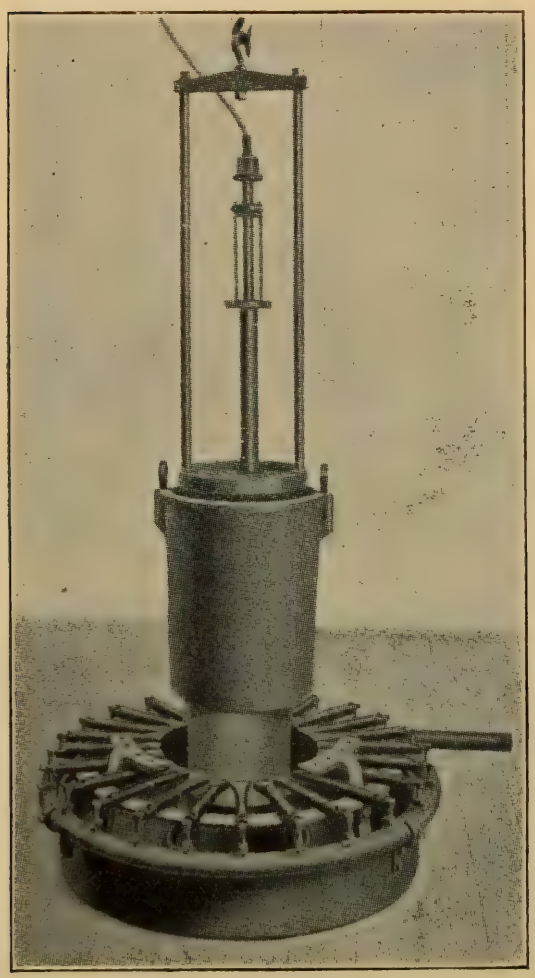


FIG. 2. Showing Interior of Furnace

itself must be proceeding regularly. Not only does the temperature of the steel cease to fall, but it actually rises. On the curve in question the rise is only about 2 degrees. In some steels this rise is as much as 30° C. After the temperature has risen and rested for a time, it again begins to fall as shown on the curve. The point where sensible cooling ceases and where there is an actual rise in temperature is the point of recalescence, and it will be noted that this point on the cooling curve is much lower than the point of absorption on the heating curve, and at first sight it might be supposed that this is due to

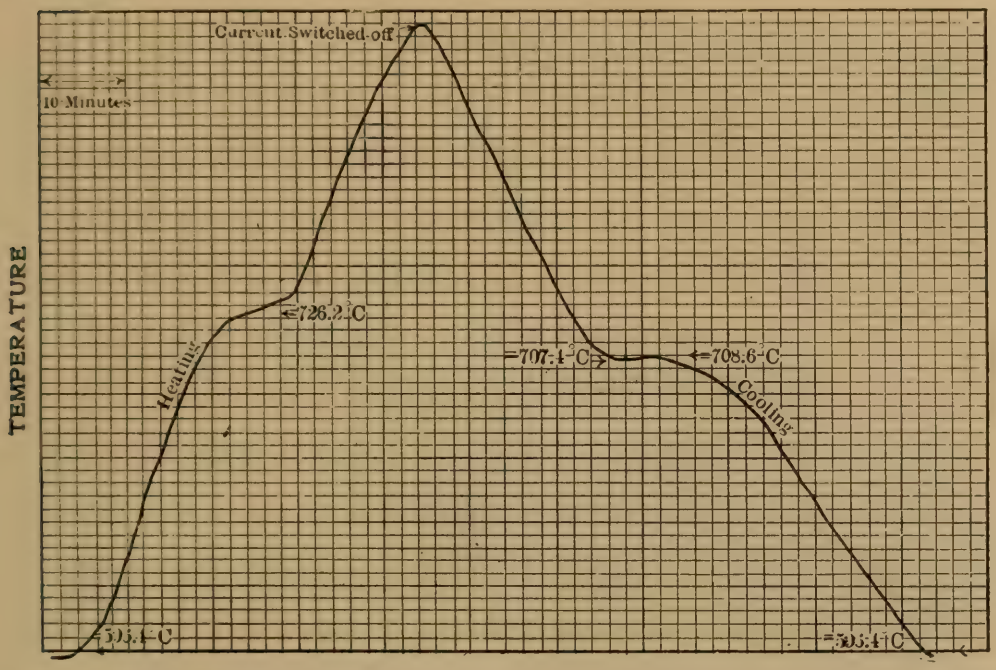


FIG. 3. Heating and Cooling Curve of Seebohm & Dieckstahl's Best Cast Steel. 1⅛ per cent Carbon

lag in the instruments on which the curves were taken. It will be observed, however, that the curves have been taken very slowly; and as a matter of fact there is very little lag to be allowed for. It is in the steel itself that this difference arises.

The other curve, Fig. 4, is of S. & D. N. C. (New "Capital") High-Speed Steel. This curve differs very remarkably from the curve of the ordinary carbon steel. Both the absorption point and the recalescence point are very gradual and it is very difficult to say where they begin and end. Mr. Brayshaw bases his treatment entirely on the curve. He has found it impossible

to harden steel, no matter how many hours it may be soaked, at any temperature below the absorption point. For good hardening the temperature must be raised so that the absorption of heat is complete, but when this has been done the temperature may be lowered very considerably so long as recalescence does not begin — that is to say (referring to the diagram in Fig. 3), the steel from which this curve has been taken must be heated to a point above 726° C., but it may then be lowered in temperature to about 710° C., and it will still harden perfectly.

By adopting this method, therefore, of heating carefully to

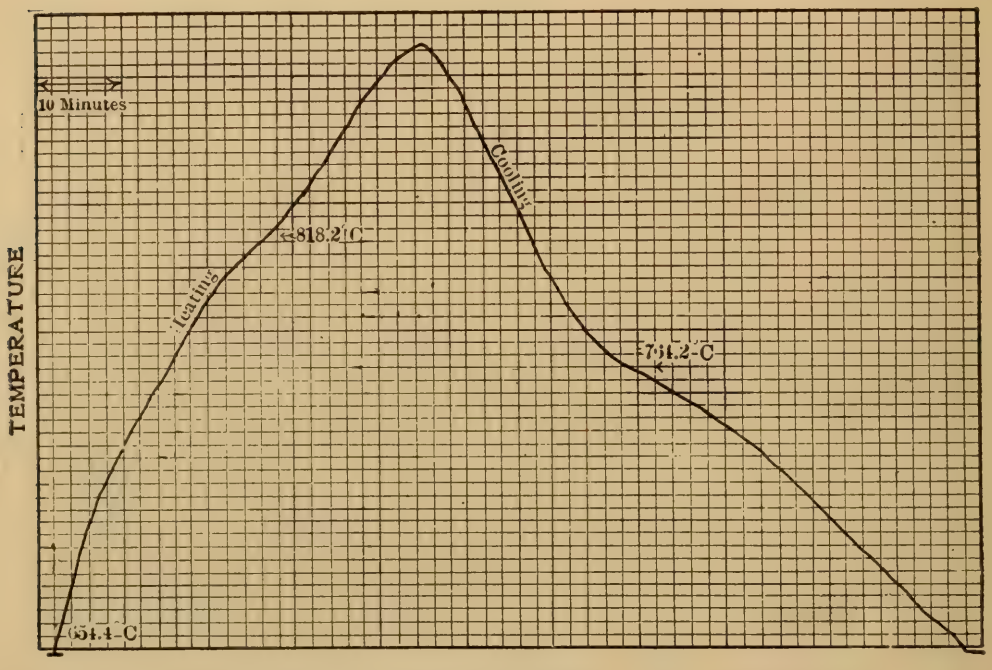


FIG. 4. Heating and Cooling Curve of Seebohm & Dieckstahl's N. C. High-Speed Steel

a point a little above the absorption point and then lowering the temperature, it is possible to harden steel at a very low point indeed, which means that the risk of breakage is eliminated and warping is reduced to a minimum.

To utilize this principle, in the design of the furnace a crucible is included for holding the salt bath, and numerous Bunsen burners provided at the base for heating crucible liquid and furnace lining, the temperature being determined by an electric pyrometer which passes through the furnace cover and rests in the bath, and is read by means of a Whipple indicator which in

Fig. 1 will be seen on the stand at the side of the furnace. By watching the indicator and regulating the burners the temperature may be raised or lowered, or it may be maintained at any point desired. A counterbalanced tray with perforated bottom, as in Fig. 2, holds the work, and the latter may be lifted clear of the bath without changing its temperature, as the whole interior of the furnace is practically at the same temperature as the salt mixture.

For handling small pieces rapidly in this furnace a set of grids or open racks are supplied, which, resting one upon another on the perforated tray, allow the liquid to reach every part of the work and bring it to its own temperature.

This furnace has been in operation for some time at the New York office of Geo. Nash & Co., 224 Pearl Street, who control the furnace in the United States.

THE ECONOMIC VALUE OF CAST IRON *

THE PRODUCTION OF MACHINE CASTINGS OF MAXIMUM STRENGTH, UNIFORMITY AND SATISFACTORY MACHINING QUALITIES

By W. H. PRETTY, Manchester Association of Engineers

IN these days of steel it is possible that insufficient attention is given to materials of construction which are still very largely employed, and which, if considered in the light of improved methods of production and operation, are undoubtedly susceptible of partaking to a greater or lesser degree in the advantages of scientific manipulation. It is beginning to be acknowledged that for some purposes wrought iron is distinctly better than steel, and it must be admitted that cast iron is yet one of the most extensively used materials in the machine shop, and yet it is only recently that the foundry and its products have been given anything like the amount of scientific attention which has long been accepted in the manufacture and use of steel. In a paper recently presented before the Manchester Association of Engineers, Mr. W. H. Pretty discusses the economic value of cast iron in the light of present shop methods, and some abstract of the paper will be found of interest.

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* " Engineering Magazine," May, 1905.

" The value of cast iron in the arts and manufactures of the world is such that it must necessarily take an important place in the great industrial questions of the day, while the vast supplies held in store for us by nature, of ores of iron and fuels, and sources of energy capable of being utilized for the production of heat by electrical or other means, are sufficient indication of its continued use by man in the future. It behooves us, therefore, as engineers, to give the subject all the attention we can to develop it to the best of our ability, and endeavor to make the founder's work a sure science. The most important applications of cast iron (under which term is included pig iron) at the present time may perhaps be broadly classed as follows:

" 1. Its use in the production of wrought iron, steel and ingot iron, etc., essentially of a metallurgical nature.

" 2. Its use in the service of mankind by civil engineers and others for structural work, bridges, tunneling, pipe lines for water supply and other purposes.

" 3. The production of castings for the general use of mechanical and electrical engineers in the construction of machinery, steam engines and other prime movers, etc.

" 4. The reproduction of works of art, ornamental ironwork, and various articles required for domestic and other purposes in times of peace.

" 5. The manufacture of malleable castings.

" The field covered is a very wide one, Class 2 is gradually passing into the hands of iron founders possessing blast furnaces, for obvious reasons, but is still practiced on a small scale by founders engaged in Class 3, while it would seem that Class 5 is likely to be replaced by steel castings."

The exact definition of the term " cast iron " is almost as difficult as the precise meaning of the term " steel." According to Professor Howe cast iron is defined as iron containing more than 2 per cent of carbon; just as he defines high-carbon steel as iron with a carbon content between 0.30 per cent and 2.00 per cent, and low-carbon steel as iron containing less than 0.30 per cent of carbon. Mr. Pretty is much less definite than this, as he broadly defines cast iron as iron with the addition of small quantities of carbon, silicon, sulphur, phosphorus, manganese and " anything else it can lay its hands on."

" Cast iron is frequently described as occupying a place in

the iron carbon series, but it is something more than this, its composition is of an exceedingly complex nature, and it should really be regarded as the product of a process in which other materials, in addition to iron, are reduced by the action of fuel and blast and enter into combination with it. In addition to these we may have compounds formed without the direct reduction of the elements, and it is not at all unreasonable to suppose that interchange between compounds and elements takes place in solution at high temperatures analogous to those we obtain in the chemical laboratory in solutions at normal temperature. It is customary to-day to judge the suitability of a pig iron for foundry purposes by the carbon, silicon, sulphur, phosphorus and manganese present. Before long we shall have to pay more attention to other elements, such as chromium, arsenic, copper, titanium, etc., and their behavior when in solution or combination with irons, in quantities so small that we to-day ignore them."

After enumerating the more frequently employed ores of iron, and the processes used in the production of pig iron, Mr. Pretty discusses the ordinary methods of grading and classifying the product. Formerly the old method of determining the character of the metal by the fracture of the pig was considered sufficient, but this can no longer be accepted. The increase in varieties, together with the changes in structure due to the production of machine-molded pigs cast in chills, demand some more precise method, and the use of a combination of chemical analysis, united with physical and mechanical tests, must be advocated. Of course an accurate knowledge of the pig is by no means everything, since the advantages of the most careful choice of materials may be completely upset in the foundry by careless working at the cupola, the use of improper fluxing materials, blast conditions, casting temperatures and other elements of manipulation.

There is no doubt that by the use of chemical and physical methods of examination, both as applied to the pig and to the resulting castings, the conditions giving any desired result may be discovered, and a repetition of any determinate series of operations be made to give a desired product.

The present interest in the introduction of rapid machining processes, including high-speed steels for the cutting tools and more powerful machine tools in which to do the work, has em-

phasized the demand of the machine shop upon the foundry for soft and easy-cutting castings. As Mr. Pretty well says, however, the question arises, Which is the more important factor, the economic value of the material, or the output of the machine departments? In many cases the strength is ample and the cost of machining is paramount, but there are many others in which the material must take premier position. Mechanical tests show conclusively that metal which would be hailed with delight and satisfaction in the shop because of its softness, may be unsuitable to meet the conditions of stress and wear which are to come upon the finished product. Mr. Pretty urges the importance of including among the tests for cast iron that of its machining quality, by the provision of test pieces to be subjected to the lathe and the drill, so that information upon this important class of properties may be included with those of resistance.

In this connection a form of standard test is given, readily available for trial in the lathe as well as in the drill-press and boring mill.

"To enumerate a few of the questions bearing upon the manipulation of cast iron throughout its treatment in the foundry we have:

"The formation of suitable slag in the cupola.

"The behavior of the blast and possible occlusion of gases in the cupola under bad working conditions.

"The addition of minute quantities of reducing agents, such as ferro-aluminum, ferro-silicon, ferro-manganese (silicon-aluminum-manganese alloys), etc., to the molten metal while in the ladle.

"The pouring temperature and the study of cooling curves by means of thermometers specially suitable for the work.

"The behavior of moisture and gases at the high temperatures suddenly brought to bear upon them, and ranging from 15° C. to 1600° C. or higher, and their behavior when in a state of occlusion, solution or inclosure in a mass of cast iron capable or incapable of yielding to the pressure produced.

"The occlusion of gases by molten cast iron and their retention or throwing off as the metal cools down to the solid state, and the effects of rapid cooling upon this phenomenon.

"The possible liberation of gases within the mass of molten

metal as it cools down, and due to molecular and chemical change other than that accounted for by occlusion.

" The effects produced by various degrees of moisture in the sand composing the mold upon the metal in contact with it, and methods of determining the percentage of moisture in the facing and other sands used in forming the molds. The shrinkage of cast iron as it cools down from the molten state, and its sudden expansion when nearing the point of solidification, afterwards followed by the usual contraction of solids as its temperature falls.

"The remelting of foundry irons and the change in character of the chemical constituents, and means of remedying this as required.

" The diffusion of metals.

" The heat treatment of cast iron and molecular rearrangement.

" The decay of cast iron under various conditions of employment, and means of remedying this.

" The effect of casting temperatures upon special chilling work.

" The study of eutectic and other alloys within a mass of cast iron, and the physical changes which accompany them.

" The various types of furnaces in use for remelting pig irons for foundry purposes, etc., and the nature of the blast capable of giving the best results."

In the United States the study of cast iron and of foundry work has been effectively conducted by the American Foundrymen's Association, and it is a matter for congratulation that a British Foundrymen's Association has recently been formed, since it is only by interested coöperation of the men who are actually doing the work that the same progress may be expected in this as has been made in other departments of metallurgical work.

THE CONSTITUTION OF IRON-CARBON ALLOYS *

STABLE AND METASTABLE EQUILIBRIA IN IRON-CARBON ALLOYS

By E. HEYN, Charlottenburg

Translated for The Iron and Steel Magazine by MILES S. SHERRILL, Massachusetts Institute of Technology

(*Concluded from page 518, Vol. IX*)

B. The Phenomena Occurring on the Solidification and Cooling of Iron-Carbon Alloys

IN this field of investigation, Professor Roozeboom † has expressed his opinions from the standpoint of the phase doctrine. I should like to consider his views a little more closely. The actual hypothesis of Professor Roozeboom has been made known to you in the preceding address.‡ I desire here merely to point out again the most important points. Professor Roozeboom takes as his basis the experimental values of Roberts-Austen,§ which, as far as they relate to the case in question, are indicated by the black dots in Fig. 18. He combines these by means of the following hypothesis: " In iron-carbon alloys below approximately 1000°, graphite is the unstable, the carbide the stable form in which carbon appears. At 1000° (along the line EF in Fig. 18) the following reaction takes place,

$$\text{martensite} + \text{graphite} \rightleftarrows \text{carbide.}"$$

Roberts-Austen had assumed in his fifth report that the branch BD in Fig. 18 corresponded to the beginning of the separation of graphite, AB to that of iron, and that the line aBc expressed the separation of the eutectic mixture of iron and graphite. Roozeboom thereupon pointed out that, along AB, not iron but mixed crystals of iron and graphite separate, and that, therefore, the eutectic is formed not of iron and graphite, but of mixed crystals *a* and graphite.

A proof for the fact that the line aBc in Fig. 18 really corre-

* " Zeitschr. f. Elektro-Chemie," Vol. X (1904), 491.

† Zeitschr. für phys. Chem.," 34, 437 (1900).

‡ " Zeitschr. f. Elektro-Chemie," Vol. X (1904), 489.

§ Fifth Report of the Alloys Research Committee, " Engineering, 210 (1899).

sponds to a eutectic which is in part composed of graphite has not been given by Roberts-Austen. Such a proof has up to the present time not been given, not even by the recent investigations of Carpenter and Keeling,* although the latter investigators without more ado follow the opinion of Roberts-Austen. One is, therefore, justified, till further evidence is advanced, in expressing doubt as to the correctness of this conception. Under the microscope, graphite is indeed often enough observed, but

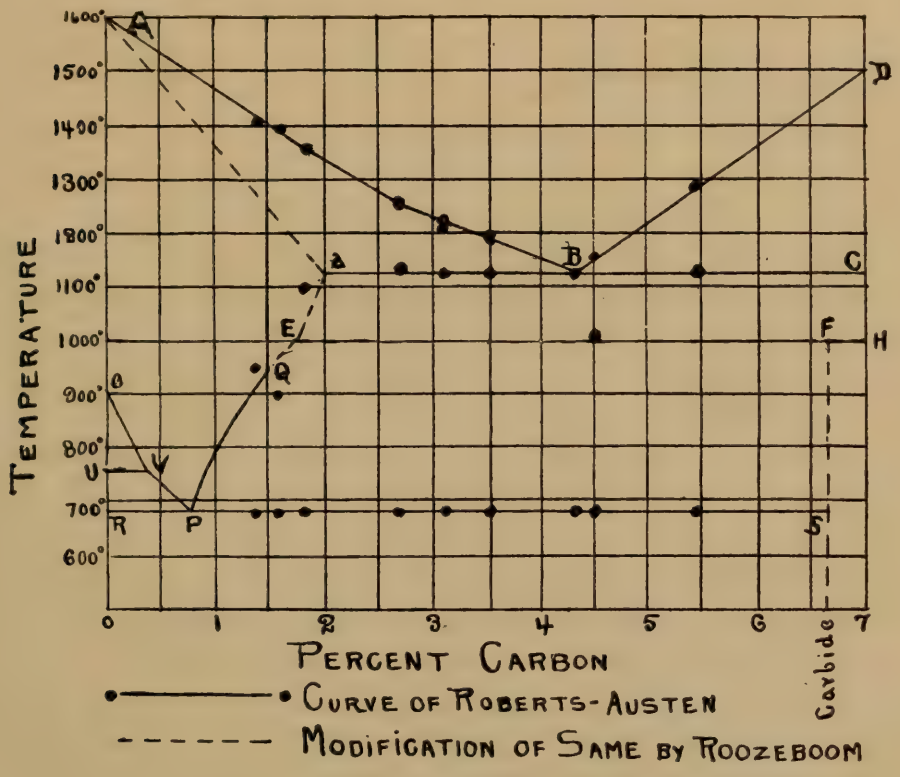


FIG. 18

never anything which resembles a eutectic of graphite and any other structural constituent.

Roozeboom has likewise accepted Roberts-Austen's view concerning the significance of the line aBc, originally expressed by Roberts-Austen. As opposed to this view, stands the fact that iron-carbon alloys low in silicon and containing up to 4 per cent carbon, as they were used by Roberts-Austen in his experiments, contain after solidification and cooling no graphite at all. In order to explain this contradiction, Roozeboom put

* Iron and Steel Institute, May, 1904.

forward the hypothesis above mentioned and expressed by the equation taking place at 1000°,

$$\text{mixed crystals E} + \text{graphite} \rightleftarrows \text{carbide}.$$

According to this, the graphite in contact with the mixed crystals E, should, at 1000°, change over into the carbide; so that after cooling, graphite should no longer be observed, but white iron free from graphite.

From the standpoint of the phase doctrine, this hypothesis fulfills all requirements; it does not, however, from the standpoint of the metallurgist. I expressed my suspicions regarding this to Professor Roozeboom at the time.

How can the incontestable fact that, under otherwise the same conditions, rapid cooling opposes and slow cooling favors the separation of graphite, be combined with the above hypothesis? The entire industry of chilled castings depends on this phenomenon. Any explanation of it by means of Roozeboom's hypothesis is so far fetched that really nothing remains of it.

I should like to call your attention to another possible explanation of the solidification phenomena of the iron-carbon alloys which can be brought into agreement with metallurgical experience on the one hand and with the solidification curve of Roberts-Austen on the other. Of course, I do not pretend to advance here a complete theory; the experimental foundation for such seems to me to be still much too insecure.* I merely wish to emphasize again that supercooling phenomena, that is, unstable equilibria, must be employed more than ever before to explain metallurgical processes, and that it is not necessary to have the phase doctrine include everything. My considerations proceed from the opinion generally accepted in metallurgical circles, that for solidified iron, graphite is the stable form in which carbon appears, and the carbide is a less stable, unstable, or metastable form. This conception is based on the fact that it is possible by annealing white cast irons which are free from graphite, to separate the carbon in graphitic form (temper carbon). Charpy and Grenet † have stated this explicitly without refer-

* Even the above-cited experiments recently carried on by Carpenter and Keeling are by no means extensive enough to render this foundation more firm.

† Bull. Soc. d'Enc., p. 399 (1902).

ence, however, to the data of Roberts-Austen or Roozeboom's hypothesis. I agree with them entirely. My conception, which I have made provisionally, is reproduced in Fig. 19.

The black full lines ABDa″c indicate the stable system iron + graphite. This system tends towards supercooling; the stable equilibrium, corresponding to the two extreme phases iron and graphite, is reached only very gradually. The solidification can take place in the supercooled, that is, metastable con-

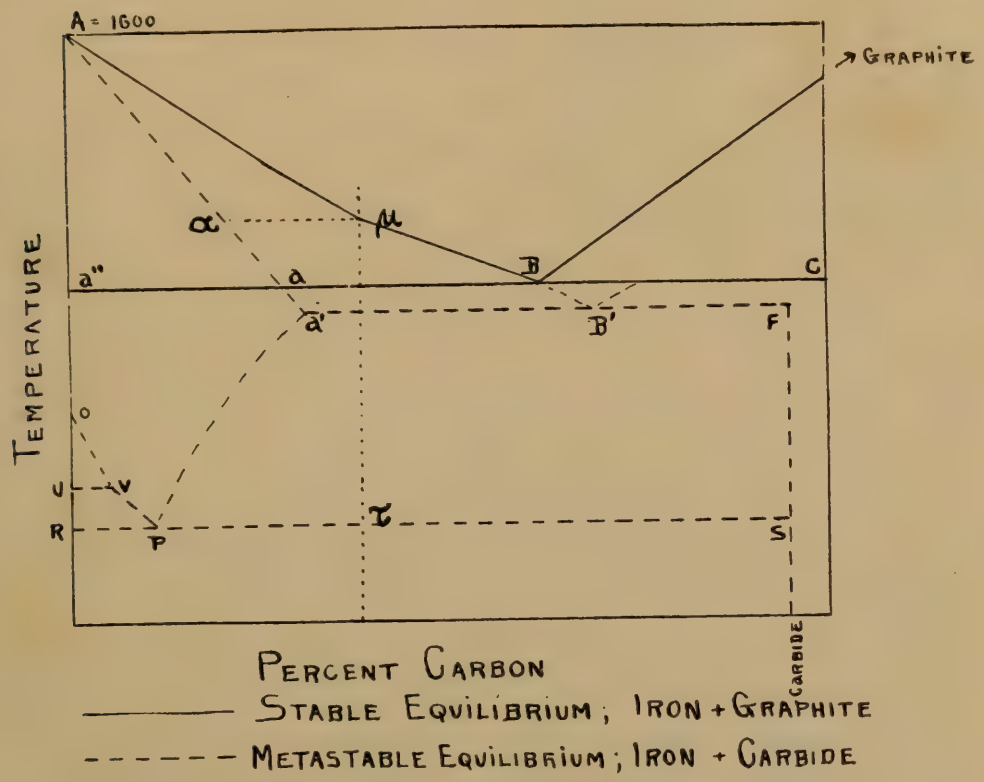


FIG. 19

dition, according to the lines Aa′B′F, etc. That is to say, pure iron crystals do not separate out of the liquid alloys, but mixed crystals of iron and carbide; neither does the eutectic B form, but the alloy, as a result of supercooling, is capable of remaining fluid below aBc; the separation of graphite is prevented. The supercooled alloy enters the lower region in which the carbide can exist in a metastable condition. The entire solidification, therefore, takes place without formation of graphite and with the separation of mixed crystals a′ and carbide. The reactions

taking place on further cooling are easily explained by means of Fig. 19.

It is probable that the possibility of supercooling exists only up to a certain maximum carbon content, which corresponds to some point lying not far to the right of B. If the carbon content of the alloy is greater than this, then along BD graphite separates out of the liquid alloy and, acting as a nucleus for further crystallization, frustrates the supercooling. Such alloys occur in technical use only exceptionally. The majority of our technically important irons lie to the left of the point B. It is a known fact that it is possible to solidify cast irons low in silicon with 3.5 to 4 per cent carbon entirely white, that is, without any separation of graphite. Here, accordingly, the tendency towards supercooling, and therefore the tendency to go over into a metastable condition, is extraordinarily marked. The presence of silicon decreases the tendency towards supercooling; such irons with a sufficient quantity of silicon approach more and more the stable solidification, with separation of most of the carbon as graphite, and the retention of small amounts of carbide in a metastable condition. If the silicon content be correctly regulated in relation to the other constituents of the cast iron, it is possible, depending on how rapidly or slowly the solidification is allowed to take place, to obtain white cast iron in the metastable condition free from graphite, or gray cast iron in which some graphite has separated, but which partly retains carbide in the metastable condition. This is, in fact, the fundamental principle of the production of chilled castings.

Manganese would favor the tendency to supercooling.

It remains still to be explained why the condition corresponding to the two phases, iron and graphite, has been accepted as stable. If white, that is, metastable solidified iron, be heated to higher temperatures,— for example to red heat,— and if at the same time, what practically is very hard to carry out, the heating is so conducted that the carbon content remains as far as possible unchanged, a decomposition takes place in the interior of the iron. Carbon separates out in a form which is known to the metallurgist as temper carbon. This kind of carbon can neither metallographically nor analytically be distinguished from graphite. It is extremely closely related to graphite, possibly even identical with it. Figure 20 shows an iron originally white,

free from graphite, in which this separation has taken place. The iron contained, before tempering, 2.49 per cent carbon, and, indeed, in a form other than graphite. After annealing for 108 hours,* it contains 2.16 per cent total carbon, of which a large proportion was in the form of temper carbon. Figure 20 shows to the right the dark temper carbon (graphite) imbedded in a light surrounding of ferrite. At some distance from this, lies well-defined pearlite, and in this to the left, cementite. The essential point to be noted is that the temper carbon lies in the neighborhood of the ferrite. At the places, therefore, where the stable condition has been reached, the two phases iron and carbon are in contact with each other. At other places cementite and pearlite still remain unchanged next to each other; there, the stable condition has not yet been reached. The occurrence of the stable condition, therefore, starts from single centers, nuclei, and spreads gradually out from them. This is a sign that the stable equilibrium is reached only very slowly.



FIG. 20. Iron 2.49 C. Annealed 108 Hours

The separation of carbon as a result of tempering is a phenomenon similar to the annealing of steel; only the degree of instability in which white cast iron, free from graphite, exists is much less than that of quenched steel. The instability is, however, sufficient to cause the metastable condition on heating to change to the stable condition, even at temperatures essentially below the line a″Bc, and, indeed, the greater the degree of instability, the lower will be the temperature at which this change can take place. Since the presence of silicon works in opposition to the supercooling, that is, increases the degree of instability of the metastable condition after it has once been formed, it is to be expected that the higher the silicon content, the lower will be the temperature necessary for the separation of temper carbon from white cast iron. This actually follows from the experi-

* Experiments by Ledebur, "Stahl u. Eisen," p. 777 (1886).

ments of Charpy and Grenet.* The presence of manganese increases the tendency towards supercooling, and, therefore has an effect opposite to that of silicon.

If the stable condition occurs only after complete solidification of the supercooled alloy, and therefore below a′B′F, then no eutectic between iron and graphite (corresponding to the point B) can be formed, but the two phases form adjacent layers as in Figure 20. Since with high silicon alloys, which after solidification contain carbon principally in the stable graphitic form, no eutectic is to be detected, it is very probable that the formation of graphite took place only below a′B′F. This formation of graphite does not take place suddenly at a constant temperature, as the line a″Bc would require if no supercooling took place, but it is extended over a range of temperature, and, therefore, renders difficult the determination of the solidification curve by pyrometric measurements. In this way, points of the line a′B′F will continually be observed and in fact more distinctly the greater the supercooling. Below this line only will heat effects of a variable character take place on account of the gradual separation of graphite. Only when the supercooling between a″Bc and a′B′F is removed, does the temperature return suddenly to the eutectic line (a″Bc); then a distinct point must be detected pyrometrically, and also a distinct eutectic structure between iron and graphite observed. Whether this case has ever been observed is not known.

If the formation of graphite take place below a′B′F, then the longer time allowed for cooling from a′B′F to a temperature where the formation of graphite is very slight, the more complete ought to be the separaton of carbon as graphite.

The separation of temper carbon in heated white iron is analogous to the process of "devitrification"; while with glass the amorphous condition is retained as a result of the supercooling, and yields to the crystalline form on devitrification; in the case of iron, the supercooled, metastable condition as well as the stable condition is crystalline. On devitrifying glasses, often together with that of raising the temperature, a mechanical effect comes into play at this temperature. This can be observed on drawing out and bending glass rods. A similar

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* *Loc. cit.*

phenomenon has been observed with highly carburized steels which have solidified free from graphite. On forging at a red heat, they show a tendency to pass over partly into the stable condition by separating carbon, that is, figuratively expressed, to devitrify. In Fig. 19 the stable system is assumed to be represented by the equilibrium between the phases iron and carbon. It appears as if this completely stable equilibrium occurs only locally in irons, for example as is illustrated by Figure 20, and as is also shown in Figure 21. The latter represents a Swedish charcoal gray cast iron with 3.7 per cent total carbon. The graphite is here imbedded in ferrite. The rest of the structure consists of pearlite.

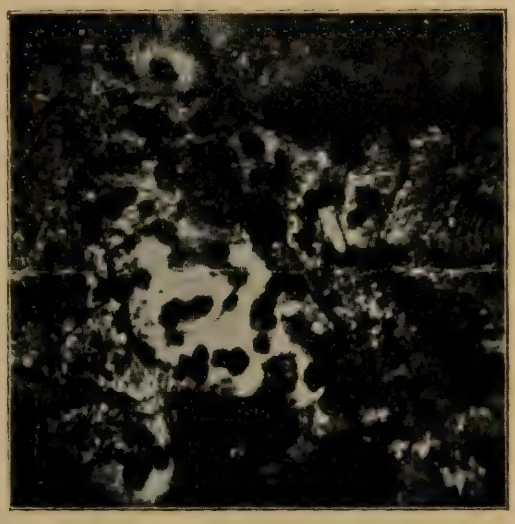


FIG. 21. Swedish Charcoal Gray Cast Iron

The metastable solidification, see Fig. 19, shows a eutectic point at B′. The solidification of irons with a higher percentage of carbon than that corresponding to the point *a′* must take place in such a way that at first mixed crystals a′ separate, that on further cooling the mixed crystals assume the composition *a′* while the mother liquor reaches the eutectic composition B′. At the temperature corresponding to the line a′B′, the metastable solidification is at an end; the solidified iron consists of crystals a′ and eutectic B′, which is itself made up of mixed crystals a′ and carbide crystals F. Just below the eutectic temperature, therefore, a structure like that indicated in Fig. 22 is to be expected. The black places correspond to the carbide. Since the line a′P slants towards the left, on further cooling the quantity of carbide must increase at the expense of the mixed crystals. The carbide forming will presumably deposit on the carbide crystals already present, and



FIG. 22

therefore, at a temperature just above τ, the structure will be similar to that indicated by Fig. 23.

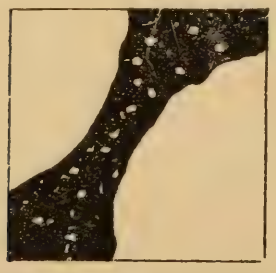


FIG. 23

As soon as the temperature τ is reached, the mixed crystals change over into pearlite. In Figure 25 such a structure as is regularly observed in high carbon irons can be easily recognized. The cementite is light colored, the pearlite appears darker and shows the composite laminated structure. In the middle of the cementite are scattered about tiny islands of pearlite, just as would be expected from our considerations. Similar pearlite inclosures can be detected in Figure 8. The above-mentioned conception of the reactions which take place on the solidification of iron-carbon alloys explains quite naturally and readily the present metallurgical processes. Whether it is correct or not can only be shown by further conscientious experiments. It is to be distinguished from Roozeboom's idea essentially in the fact that I consider the transformation

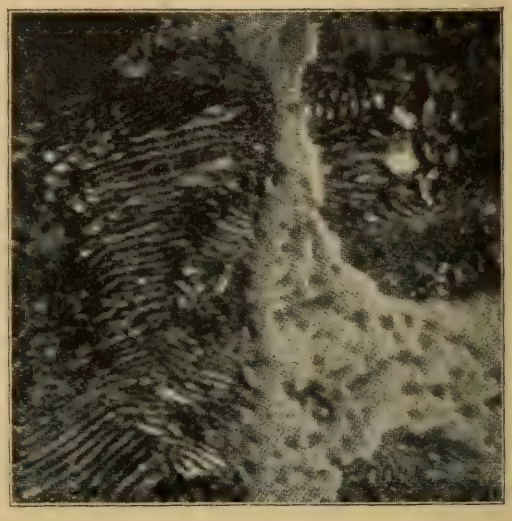


FIG. 25. High Carbon Steel

$$\text{martensite} + \text{graphite} \rightleftarrows \text{carbide}$$

not to be supported by experimental data, and therefore as unnecessary.

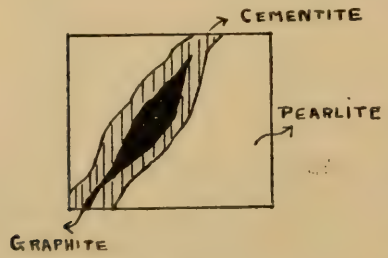


FIG. 24

Metallographic results directly contradict this transformation. If a cast iron in which both graphite and cementite occur, be considered, then, if according to Roozeboom cementite is formed, as in the reaction above, from martensite and graphite, it is to be expected that graphite and cementite will lie directly next to one another as in Fig. 24; that is, a kind of contact meta-

morphosis would occur. This, however, never occurs. The graphite always lies as far away from the cementite as is possible, as is distinctly seen in Figures 26 and 27. Both pictures represent a mottled cast iron. In the former, the graphite appears dark, imbedded in a finger-shaped part of the structure which is shown by Figure 27 to be pearlite. The raised little islands, located at a considerable distance from the graphite, are cementite, which in their turn, as already mentioned above, inclose tiny spots of pearlite.

It remains still to be pointed out that in Fig. 11 the exact positions of the individual parts of the diagram have not been firmly established; it is supposed to represent the essence of the matter only qualitatively and not quantitatively. The two lines



FIG. 26. Mottled Cast Iron

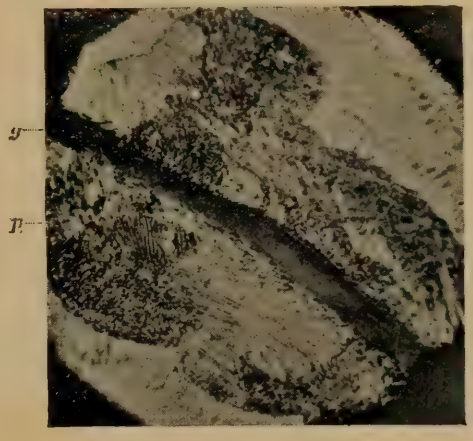


FIG. 27. Mottled Cast Iron

a″Bc and a′BF may possibly lie very close to one another. It is undetermined whether a″Bc in Fig. 19 corresponds to the line aBc in Fig. 18; that is, whether that which Roberts-Austen observed really corresponded to the stable condition. Corresponding to this case, Fig. 19 is drawn with reference to Fig. 18. This is probably not the case. It is more probable that a″Bc in Fig. 19 was passed by in the observations by Roberts-Austen, and that he in reality observed the line a′B′F (Fig. 19) and gave it a false signification, and that, therefore, both lines a″Bc and A′B′F in Fig. 19 should be moved up by a certain unknown amount.

Further investigations concerning the solidification reactions are of the highest importance for the foundry practice. It is, for

example, still an open question whether, in irons containing silicon whose tendency towards supercooling has been decreased, and in which, therefore, partly metastable, partly stable, reactions take place, the latter already take place while the liquid mother liquor is still present, or whether the appearance of the graphite formation with partial replacement of the metastable equilibrium results below the line a'F only. It is also not impossible to have both reactions taking place simultaneously.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

EXPERIMENTS on the Fusibility of Blast-Furnace Slags. O. Boudouard. Iron and Steel Institute, May, 1905, meeting. 20,000 w., illustrated. — The author conducted an extensive series of experiments dealing with the fusibility of blast-furnace slags which are described at length in his paper. His conclusions are as follows:



" 1. The softening temperatures of slags which I have determined during the course of these investigations may be regarded as practically their temperatures of fusion. Numerous observations clearly show that no greater difference exists between these two temperatures than exists between any temperatures of observation referred to actual temperatures below 1500° C.

" With regard to the difference existing between the temperature of formation of a slag and that of its fusion, it is, according to my observations on the dicalcic silicate and on the

* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

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aluminate of calcium Al_2O_3, 1.8CaO, equally permissible to regard it as no greater than the amount which would fall within the permissible limits of probable error. The conditions under which I worked, *i. e.*, with intimate mixtures of finely powdered constituents, were highly favorable to this conclusion. In blast-furnace practice when the fluxes are added in more or less large pieces, and more or less well mixed, the temperature of formation of the slag is certainly higher than that of its fusion, but it will the more closely approach it the more intimate and complete the previous mixture of the materials has been. For a given slag the temperature of fusion that I obtained can, therefore, be regarded as the minimum temperature of formation; and in ordinary blast-furnace practice there is certainly an economy of fuel to be realized if the fluxes added have been previously crushed and mixed.

" 2. I have determined the fusibility curves for the silicates and aluminates of lime at the same time that I completed those for the silicates of alumina. The fusion point of silica is equal to 1830° C.

" The examination of the fusibility curves of silicates and aluminates of lime show that the addition of a small quantity (about 10 per cent) of silica or of alumina to the lime is enough to lower the fusion point considerably. The phenomenon is less pronounced with the addition of lime to alumina; nearly 40 per cent of lime must be added to cause the mixture to melt at 1500° C. One finds, in the French translation of Ledebur's ' Treatise on Metallurgy,' * that slags into the composition of which only silica and lime enter are often infusible. According to my experiments, slags containing 30 to 90 per cent of lime have fusion points below or at least equal to 1500° C.

" 3. *The Existence of Definite Compounds*, SiO_2CaO, SiO_22CaO, SiO_23CaO; Al_2O_3CaO, Al_2O_32CaO, Al_2O_33CaO, the preparation and properties of which have already been described, has been confirmed by the indications of the fusibility curves.

" 4. A triangular diagram, to which are added numerous complementary curves, summarizes the extent of our knowledge of the fusibility of alumino-calcic silicates. It focuses and extends the conclusions arrived at by Akerman and Gredt.

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* Paris, 1895, Vol. I, p. 202.

"In a general way the addition of alumina to a silicate of lime first raises the fusibility, which ascends to a maximum, and ultimately lowers it. The more basic a silicate is, the higher must its alumina content be to make it fusible.

"*Influence of the Index.* — The following table gives the composition of slags at the maximum fusion points:

	Percentage Composition			
Index	SiO_2	Al_2O_3	CaO	Temp.
0.5	23.6	17.8	58.6	1430°
0.5	26.6	40.2	33.2	1460°
1.0	40.0	22.7	37.3	1345°
2.0	57.1	16.2	26.7	1300°
3.0	66.7	12.6	20.7	1325°

"*Substitution of Alumina for Lime, the Percentage Proportion of Silica remaining Constant.* — For silica percentages higher than 30.0 the fusibility rises markedly up to 25 per cent of alumina, to fall rapidly beyond this percentage.

"For silica percentages of 30 the fusibility varies but little up to 35 per cent of alumina. Beyond this it falls rapidly.

"For slags with less than 30 per cent of silica there is a notable increase in the fusibility up to 50 per cent of alumina. Beyond this the fusibility diminishes very rapidly. The curves usually present two minima.

"The table below gives the composition of the slags at the minimum fusion points.

SiO_2	Al_2O_3	CaO	Temp.	SiO_2	Al_2O_3	CaO	Temp.
5.0	40.0	55.0	1360°	20.0	22.5	57.5	1425°
,,	50.0	45.0	1370°	20.0	50.0	30.0	1450°
10.0	7.5	82.0	1460°	30.0	17.5	52.5	1435°
,,	35.0	55.0	1370°	40.0	25.0	35.0	1350°
15.0	32.5	52.5	1380°	50.0	10.0	40.0	1340°
,,	52.5	32.5	1455°	60.0	20.0	20.0	1350°
				70.0	10.0	20.0	1360°

"I have given in the following tables the relative proportions of alumina and of lime corresponding to the maximum and minimum fusibility of slags containing increasing increments of silica:

SiO_2	Temp. Min.	Al_2O_3	CaO	Temp. Max.	Al_2O_3	CaO
10 per cent	1460°	7.5	82.5	1510°	.....	90.0
,,	1350°	37.5	52.5	>1850°	>75.0	<15.0
20 per cent	1465°	,,	80.0	1490°	5.0	75.0
,,	1425°	22.5	57.5	1510°	40.0	40.0
,,	1450°	50.0	30.0	>1850°	>72.0	< 8.0
30 per cent	1435°	,,	70.0	1455°	5.0	65.0
,,	1420°	15.0	55.0	>1850°	>65.0	< 5.0
40 per cent	1350°	25.0	35.0	1445°	,,	60.0
,,	,,	,,	,,	1880°	60.0	,,
50 per cent	1325°	15.0	35.0	1440°	,,	50.0
,,	,,	,,	,,	>1800°	>47.5	< 2.5
55 per cent	1300°	17.5	27.5	1425°	,,	45.0
,,	,,	,,	,,	>1800°	>43.0	< 2.0
60 per cent	1325°	19.0	21.0	1400°	,,	40.0
,,	,,	,,	,,	>1800°	>39.0	< 1.0
70 per cent	1360°	10.0	20.0	1500°	,,	30.0
,,	,,	,,	,,	>1750°	>28.0	< 2.0
80 per cent	1500°	7.5	12.5	>1750°	< 2.0	>18.0
,,	,,	,,	,,	>1700°	>18.0	< 2.0

" 5. The triangular diagram constitutes a perfect chart, enabling metallurgists to determine without difficulty the fusion temperature of a given alumino-calcic silicate; and one of the important factors in the satisfactory running of a blast furnace is a knowledge of the degree of fusibility of a slag. The calculation of the ore mixture is actually carried out by the stoichiometric method. The employment of this method necessitates a complete acquaintance with the chemical composition of the slag; the considerations are therefore based upon comparisons. But as the number of substances that may enter into the composition of a slag is considerable, and as the burdens are usually of a very variable nature, it is in most cases impossible with the ores and fluxes available to reproduce at will a silicate of the chosen type; hence it is necessary to rest content with finding a compound that will approximate as closely as possible to it in its essential characteristics, *i. e.*, particularly in its degree of fusibility.

" In metallurgical operations it is very rarely that slags are produced containing nothing beyond silica, alumina and lime; there is always more or less magnesia, manganese and oxides of iron present. Nevertheless it is amongst this class that the great bulk of slags produced in the manufacture of pig iron falls.

Quality of Pig Iron.	Source of Origin.	SiO_2.	Al_2O_3.	MgO.	CaO.	MnO.	FeO.	Alkalis.	CaS.	Acidity.	Temp.
Grey charcoal pig iron	Groeditz (Saxony)	63·98	3·33	0·88	22·55	5·53	1·82	3·33	0·03	2·3	1430°
	Flensberg (Hartz)	56·89	6·38	2·64	28·46	2·01	1·72	1·30	,,	2·3	1375°
	Rübeland (Hartz)	53·79	13·04	0·57	25·67	2·20	2·44	,,	,,	2·0	1330°
	Zorge (Hartz)	49·30	12·17	2·28	31·23	0·95	0·79	2·61	0·43	1·8	1325°
Grey pig iron, from coke or coal	Mülheim on Ruhr	27·50	9·75	1·37	58·90	,,	,,	,,	,,	0·66	1445°
	,, ,,	31·37	13·09	1·16	52·04	,,	,,	,,	,,	0·75	1425°
	,, ,,	31·20	10·81	1·08	53·17	,,	,,	,,	,,	0·80	1440°
	,, ,,	32·20	8·17	,,	48·92	4·79	,,	,,	,,	0·90	1445°
	Unknown source	37·10	16·70	1·90	38·50	0·70	0·40	,,	4·10	1·00	1375°
	,, ,,	35·40	9·20	2·30	47·20	0·40	0·40	,,	4·60	1·00	1410°
	Luxemburg	37·38	10·94	1·99	46·14	0·72	1·00	,,	,,	1·00	1380°
	English clayband ores	27·65	24·69	3·55	36·56	0·35	0·72	1·45	4·39	0·60	1440°
		40·51	19·56	1·09	30·80	,,	1·20	,,	2·61	1·10	1350°
White pig iron	Lower Rhine	42·23	9·84	1·32	37·13	0·97	2·60	,,	4·32	1·3	1375°
	"Vulcan"	31·92	9·83	2·03	46·73	3·78	0·71	,,	4·36	0.9	1430°
Foundry pig	Pont-à-Mousson	31·84	20·64	2·49	43·12	,,	1·03	,,	,,	,,	1425°
Basic pig iron	Denain	31·0	14·0	,,	48·00	1·50	2·50	,,	,,	,,	1425°
	Longwy	32·60	16·5	,,	46·00	2·00	2·50	,,	,,	,,	1425°

"Using the practical data to be found in metallurgical treatises (Ledebur, Babu), I have determined the fusion temperatures of industrial slags derived from various sources. They are as follows:

Description of Slag	Percentage Composition				Temperature
	SiO_2	Al_2O_3	CaO*		
Ferro-silicons with 14 per cent	25.0	25.0	50.0		1450°
	35.0	25.0	40.0		1375°
Gray hot-blast charcoal pig iron	45.0	10.0	45.0		1360°
	65.0	5.0	30.0		1430°
Gray hot-blast coke anthracite and coal pig iron	30.0	20.0	50.0		1420°
	35.0	10.0	55.0		1420°
White pig iron — 1. Charcoal	45.0	10.0	45.0		1360°
	40.0	5.0	55.0		1425°
White iron — 2. Coke	30.0	10.0	60.0		1440°
	40.0	5.0	55.0		1425°
			CaO	MnO	
Spiegeleisen	30.0	10.0	55.0	5.0	1440°
	40.0	10.0	10.0	40.0	1440°

The temperatures given in the last two tables are obviously only approximate, but if the conclusions of Akerman who describes the influence of foreign oxides on the fusibility of alumino-calcic silicates be borne in mind, and it be remembered that as a general rule a slag is more fusible the larger the number of constituents it contains, the data given above will, notwithstanding, furnish information of value to metallurgists, inasmuch as it represents the maximum fusion temperatures of slags corresponding to a given chemical composition. **No. 380.**

The Electro-Metallurgical Industries. J. B. C. Kershaw. "The Electrical Age," April, 1905. 4,800 w., illustrated. — This article includes a short description of some of the most successful electrical methods for the production of iron and steel. **No. 381. C.**

Electric Power in Steel Works. "The Engineer" (London), April 28, 1905. 1,200 w., illustrated. — A description of a number of special applications of electric motors to steel works machinery, including turning tackle for forging, charging machines, roller tables and special overhead travelers. **No. 382. B.**

* Under the term "lime" has been included all the oxides other than silica and alumina.

An Automatic Stock-Line Recorder for Iron Blast Furnaces. J. E. Johnson, Jr. A paper read at the February, 1905, meeting of the American Institute of Mining Engineers. 4,000 w., illustrated. — The author describes a patented device consisting of: (1) a test rod suspended at its top by a chain, but normally resting on the stock and descending with it except when the bell is open; (2) a simple mechanism for lifting this rod out of the way of the in-coming stock at the latter period; and (3) an attachment for recording its motion on a reduced scale. **No. 383.**

Experiments Relating to the Effect on Mechanical and Other Properties of Iron and Its Alloys Produced by Liquid-Air Temperatures. R. A. Hadfield. Iron and Steel Institute, May, 1905, meeting. 35,000 w., numerous illustrations. — From the results of an exhaustive set of experiments dealing with the effect on mechanical and other properties of iron and its alloys produced by liquid-air temperatures the author arrives at the following conclusions:



"It is very clear that as regards iron and iron alloys, with, however, certain exceptions, the effect of low temperatures is to increase in a remarkable degree its resistance to tensile stress, ordinarily known as the breaking load or tenacity, and to reduce its ductility, as measured by elongation, from the highest point, for example, in mild steel 30 to 40 per cent, to practically *nil*. The changes take place to the same extent, and this is very curious, in the softest wrought iron as represented by the specimens 'S.C.I.,' 'L.S.S.' (the famous Swedish melting iron) and also English wrought iron, and in carbon steel samples from 0.10 per cent or 0.20 per cent to the high percentages such as 1.25 per cent or 1.50 per cent. Thus the absence or presence of carbon in ordinary carbon steel in which other special elements are not present seems to have

but little influence. That there is no error in this statement is proved, independently of the tensile tests, by the fact that several bars of the 'S.C.I.' and mild steel specimens were submitted to the low temperature test, and tested by hand hammer immediately after immersion. In all cases they exhibited great brittleness, breaking off instantly upon being struck with the hammer; there was an entire absence of ductility.

"Further confirmation is obtained by the Brinell hardness ball test, a method of testing explained elsewhere. Under this test the 'S.C.I.' specimen at normal temperature had a hardness number of 90, whereas when tested at about —182° C. this increased to no less than 266, or about equal to the hardness of 0.80 per cent carbon steel at normal temperature. This almost seems incredible when it is remembered that the 'S.C.I.' shows by analysis 99.82 per cent of iron, and normally has only 20 to 22 tons tenacity with 25.30 per cent elongation.

"The importance of the discovery of the toughening effect of nickel upon iron at low temperatures will be seen when it is understood that whilst it has been well known that nickel in certain percentages produced important improvements in the qualities and properties of iron and steel alloys no microscopical or chemical research work has yet proved why this came about. To the author it seems clear that these experiments go a long way towards offering a satisfactory explanation.

"It will be seen that the purest iron, as represented by the 'S.C.I.' containing 99.82 per cent iron and of specially high quality and purity, becomes brittle to an extraordinary degree under the influence of the low temperature —182° C., whereas nickel itself tested at the same low temperature has improved rather than deteriorated, not only in tenacity, which iron also does, but in ductility, in which latter quality iron entirely breaks down. If nickel, therefore, is present in an iron alloy containing but little carbon or comparatively low in that element, it acts as a preventive of brittleness, or is a very considerable modifier of that objectionable quality.

"It may be interesting to state that at ordinary temperatures the toughness or ductility of nickel is no greater than that of iron. For example, in comparative tensile tests, made by the writer, of nickel and pure iron, the ductility of iron was greater. The reduction of area in the material generally shows its condition

as regards ductility; in the specimens in question the reduction of area in the tensile test bars was nearly 20 per cent greater for iron in both the author's ' S.C.I.' and Arnold's pure iron than in the nickel specimen tested.

" Iron to a more or less degree, at any rate in manufacturing operations, always seems to be endeavoring to wander out of the ' paths ' of ductility and toughness; it is constantly endeavoring to become brittle. It will often assume its apparently brittle nature on the slightest provocation, and the metallurgist by his arts is always trying to correct this tendency. As with humanity, there seems to be a law of tendencies, and iron by heredity is constitutionally weak. It would appear, therefore, that iron, a cheap and convenient metal itself, must be permeated by some element that will mask or modify its properties. Until comparatively recently carbon was the only element known to modify the properties of iron; but as will be seen in this research, this element, where great toughness is required, only helps to make matters worse.

" Fortunately for iron, however, its close companion, nickel, singularly enough in the same group, comes along and acts as a friend in keeping it — iron — up to the mark and preventing it from wandering out of the narrow road of metallurgical rectitude, that is, of toughness or ductility. Exactly why this should be so cannot easily be explained, but this is the fact. Possibly some interpenetration of the atomic mass causes a change which cannot as yet be deduced by any known chemical investigations. Iron, too, is a very crystalline metal, whereas nickel appears to be much more amorphous; it is possible, therefore, that nickel tends to prevent iron crystallizing in this manner, or prevents it cooling in such large or dangerous type of crystals. This action of nickel is simply marvelous in certain of the alloy specimens; for example in an alloy of iron, carbon 1.18 per cent, nickel 24.30 per cent and manganese 6.05 per cent. Here the ductility is extraordinary at not only ordinary but low temperatures, probably the highest known for any iron alloy, and certainly for an alloy having such tenacity as 84 tons per square inch. There is still present in this alloy 68 per cent of iron, yet the tendency of the latter metal to wander into the paths of brittleness is not only entirely checked at the liquid-air temperature — and this brittleness, as shown so

clearly in this research, occurs to an extraordinary extent in pure iron cooled to —182° C. — but the elongation or ductility already so great is considerably increased, namely, from 60 per cent to 67½ per cent. There is also an increase of tenacity in both cases, namely, a rise of from 10 to 38 per cent. Thus the nickel present — as these results cannot apparently be ascribed to any other cause — enables the bar under this high tension and at —182° C. to remain far more ductile than the very best of ductile iron of one third the tenacity. Although the action of nickel has been specially referred to, it must not be overlooked that in this alloy there is also present 6 per cent of manganese, which in its ordinary combination with iron, that is, with no nickel present, would confer intense brittleness upon the iron and render it more brittle than if not present. This treble combination of nickel-manganese with iron appears to reverse all the known laws of iron alloys.

" M. Osmond's theory as regards these iron-nickel-manganese alloys is that manganese acts here in the nature of nickel. He considers that 1 per cent of manganese is equivalent in its action upon iron to 2 per cent of nickel.

" In conclusion, it may be said that the many extraordinary changes brought about in the physical properties of iron and its alloys could not have been deduced from any known laws. Iron in the main is ' embrittled ' to an extraordinary degree by liquid-air temperature, and yet it will be seen that this ' hereditary ' tendency can be entirely checked in certain of its nickel-iron and nickel-iron-manganese combinations.

" These various changes appear to be certainly not chemical, and it is rather to the physicist we must eventually look for a full and correct explanation of the many curious results obtained in this research." **No. 384.**

The Electrical Driving of Rolling Mills. " The Iron and Coal Trades Review," April 21, 1905. 2,000 w., illustrated. **No. 385. B.**

Microscopic Observations on Naval Accidents. Part II. Thomas Andrews. " Engineering," May 5, 1905. 2,000 w., illustrated. — A report of the microscopical examination of a portion from the propeller tail shaft of a large screw steamer, which had fractured in service. **No. 386. B.**

Accidents Due to the Asphyxiation of Blast-Furnace Workmen. B. Thwaite. Iron and Steel Institute, May, 1905, meeting. 4,500 w., illustrated. — The author after describing the nature and escape of blast-furnace gas suggests the following precautions in order to secure comparative immunity from fatalities due to asphyxiation:



" 1. Where practicable, all gas flues and gas pipes should be placed above the ground, and, if possible, above the breathing level.

" 2. If the gas flues are underground they should be built of blue bricks set in cement.

" 3. Gas-flue manholes should be equipped with lids that will secure the maintenance of perfect gas tightness.

" 4. All habitable buildings should be thoroughly well ventilated. The ground surface below the building should be covered with a layer of cement concrete, and an open-air space should be formed between the cement surface and the flooring boards of the building.

" 5. Forced ventilation should be the principle adopted for all occupied buildings in iron and steel works. An air supply tapped from the cold-blast main may be found useful in this connection.

" 6. The gas engine exhaust pipes should terminate at a considerable altitude above the works floor, and part of the air drawn into the air-tub of the blowing-engine should be supplied from the engine house.

" 7. Especial precautions should be taken during flue- and stove-cleaning periods, and in blowing-in furnaces.

" 8. Enamel lettered warning-notices should be prominently posted throughout the works.

" 9. Fines should be imposed on workmen for gas risks carelessly undertaken.

" 10. A paid ambulance corps should be established.

" 11. During the blow-out period of slag-tapping operations the men should be withdrawn from the zone of gas-escape.

" 12. The time allowed to be occupied in gas-producer poking operations for individual men should be limited to three minutes.

" 13. The reversing valve-pits of gas-fired furnaces should be well ventilated.

" 14. Roll-call checks of labor employed in gas-flue and stove-cleaning operations should be established.

" 15. If power gas-pipes have to be placed underground, they should be placed in grate-covered open trenches, and the pipe-flanges should be planed." **No. 387.**

Cast-Iron Car Wheels. J. E. Muhlfeld. "The Railroad Gazette," May 5, 1905. 2,500 w. — The author's concluding remarks are given below:

" In conclusion it would appear that the past and present undesirable performance of the cast-iron wheel may be overcome:

" *First*, by designing a partial or full double plate which will distribute the metal to provide ample flexibility between the hub and the tread; strengthening directly below the rim by reinforcement of more gray iron to prevent extreme chilling and cross and longitudinal cracking; removing the depth of the metal at the tread and rail contact, which will increase the chill at the greatest wearing point; increasing the metal at the base of the flange with more gray iron to draw the chill and strengthen the throat, and providing a tread and throat contour which will relieve severe frictional contact at the throat of the flange with the brake shoe and rail.

" *Second*, by the use of a uniformly good material and proper foundry practices processes and equipment.

" *Third*, by specifications, guarantees inspections and tests of sufficient severity to insure a proper degree of endurance, mileage and safety.

" *Fourth*, by a flexible suspension of the brake beams that will prevent the liability of severe friction between the brake shoe and the throat of the flange, or concentrated pressure on the rim, either on straight track or when curving.

" *Fifth*, by the adoption of simple and substantial anti-

frictional side bearings and center plates, lateral motion truck device and adequate side movement for the couplers the design of which will not be discussed in this paper although their application should be given serious consideration in connection with the use of either cast-iron or steel wheels.

" *Sixth*, by adopting a rail head section that will conform more closely to the contour of the wheel flange.

" A construction such as recommended might bring the cast-iron wheel to such a state of perfection as would make its use practicable, safe, efficient and economical in connection with the heaviest capacity freight locomotive tender and car equipment.

" Considerable thought has been given recently to the advisability of substituting the steel wheel for the cast-iron wheel. The value of such a step is as yet only problematical. If steel wheels as manufactured to-day were used in place of good cast-iron wheels for freight cars the investment in the United States would be approximately $200,000,000 more than at present, or a sum sufficient to fully equip 3,500 miles of modern American railroad. It therefore appears that every opportunity should be given to perfecting the cast-iron wheel which has given such good service under the lighter equipment, until it can be made to meet the present and future requirements or until a steel wheel can be produced that can insure equivalent or greater efficiency and economy." **No. 388. B.**

R. A. Hadfield's Presidential Address. The Iron and Steel Institute, May meeting 1905. 40,000 w., many tables and illustrations. — In this intensely interesting address the author deals with most of the problems of moment to iron and steel metallurgists. The address also includes the portraits of many past metallurgists and scientific men, five of which will be found reproduced in our frontispiece, as having been more closely connected with the iron and steel industry. They are: René Antoine Ferchault Réaumur (France), 1683–1757, physicist; wrote on cementation and decarburization.

Emanuel von Swedenborg (Sweden), 1688–1772, engineer and theologian; wrote on iron.

Benjamin Huntsman (England), 1704–1776, manufacturer; first to melt steel.

Torbern Olaf Bergman (Sweden), 1735–1784, chemist;

founder of analytical chemistry, drew distinction and explained differences between pig iron, wrought iron and steel.

Henry Cort (England), 1740–1800, engineer; introduced puddling and the use of grooved rolls. **No. 389.**

Wrought Pipe Threading and Durability. F. N. Speller. Read at the annual meeting of the Canadian Mining Institute, Montreal, Canada, March 1–3, 1905. 3,000 w., illustrated. — The author recalls the opinion of recent investigators, and notably those of Prof. H. M. Howe, regarding the relative value of wrought iron and low carbon steel for the manufacture of tubes, and describes some experiments conducted in the laboratory of the National Tube Company, McKeesport, Pa. "Mild steel," the author writes, "has had to live down prejudice in nearly every line where it has displaced wrought iron. The most suitable quality of Bessemer steel for pipe manufacture has been the result of much extensive experimenting and has proven much more satisfactory in welding. Naturally the makers of wrought-iron pipe to whom a supply of suitable steel is not available make the most of the suspicion which the word 'steel' still raises in the minds of some people not informed on the modern advances in this industry. It seems quite reasonable to suppose that the advantage of superior strength, ductility, homogeneity, finish, and lower cost, which accompanies the use of steel pipe, would be more generally recognized if such misapprehensions as these regarding threading and corrosion were cleared up." **No. 390.**

Air Blast for the Foundry Cupola. W. H. Carrier. "The Iron Age," May 11, 1905. Abstract of a paper read before the Buffalo Foundrymen's Association, April 18, 1905. 2,200 w. — The author presents some arguments in favor of the fan over the positive blower to provide the blast for a foundry cupola. **No. 391. B.**

Gas Blowing Engines. Tom Westgarth. "The Engineer" (London), May 5, 1905. Abstract of a paper read before the West of Scotland Iron and Steel Institute. 2,500 w., illustrated. — The author describes some of the best-known gas-blowing engines, and comments critically upon their performance. **No. 392. B.**

The Fremont Method of Determining the Fragility of Iron and Steel. T. Y. Olsen. A paper read before the Engineers' Club of Philadelphia, Pa., December 3, 1904. 3,000 w., illustrated. — A critical discussion of the well-known Fremont impact test. **No. 393.**

Slag Cement. W. B. Ruggles. "The Iron Age," May 18, 1905. 2,200 w. — The author gives evidences of the high quality of slag cement, which he claims "compares favorably with the best brands of Portland cement for at least 90 per cent of all the work for which cement is used." **No. 394. B.**

Roll Turning: An Important Mechanical Feature in the Iron and Steel Industry. W. S. Standiford. "The Engineering Magazine," June, 1905. 7,000 w., illustrated. **No. 395. B.**

METALLURGICAL NOTES AND COMMENTS

The May, 1905, Meeting of the Iron and Steel Institute

The thirty-sixth annual meeting of the Iron and Steel Institute was held at the Institution of Civil Engineers, in London, May 11 and 12. The report of the Council stated that during the year 1904 there were added to the register 213 names, bringing the total roll of membership on December 1, 1904, to 1,910. The following Andrew Carnegie Research Scholarships, each of £100, were awarded by the Council: H. C. Boynton (Cambridge, Mass.), L. A. Guillet (Paris) and W. H. Hatfield (Sheffield), while further grants of £50 each were made to P. Breuil (Paris), Dr. H. Carpenter (National Physical Laboratory), Messrs. E. G. L. Roberts and E. A. Wraight (London) and W. Rosenhain (Birmingham).

The retiring president, Mr. Andrew Carnegie, in a very happy speech introduced Mr. R. A. Hadfield, who, after a brief reply, presented the Bessemer gold medal to Prof. J. O. Arnold of Sheffield. Professor Arnold returned his thanks and the president then delivered his address.

The following papers were read and discussed:

"The Continuous Steel Process in Fixed Furnaces," by S. Surzycki.

"Developments of the Bertrand-Thiel Process," by John H. Darby and George Hatton.

"The Effect of Liquid-Air Temperatures on Iron," by R. A. Hadfield, President.

"The Cleaning of Blast-Furnace Gas," by Axel Sahlin.

"Dry-Air Blast" (Supplementary Paper), by James Gayley.

"Fatigue in Metals," by Sidney A. Houghton.

"The Fusibility of Blast-Furnace Slags," by O. Boudouard.

"Asphyxiation of Blast-Furnace Men," by B. H. Thwaite.

"Sulphur in Coke and in the Blast Furnace," by Prof. F. Wuest and F. Wolff.

An abstracted report of the research work of the Carnegie scholars during 1904–1905 was also presented and discussed It included abstracts from the following reports:

" Heating and Cooling of High-Speed Tool Steels," by H. C. H. Carpenter.

" Effects of Reversed Stresses in Steel," by J. C. Gardner.

" (*a*) Troostite and (*b*) Heat Treatment and Fatigue of Steel," by F. Rogers.

" Magnetic and Electric Properties of Steel," by Gunnar Dillner and A. F. Enström.

Some of the papers read at this meeting will be found reproduced either in full or in part in the present issue of *The Iron and Steel Magazine*, while the others will be dealt with in subsequent issues.

Practical Micro-Metallography. — Mr. J. E. Stead recently read two papers before the Royal Microscopical Society of London which are briefly summarized in the " Journal " of that Society for April, 1905.

In illustration of the subject a series of views were shown upon the screen, the first twenty of which showed the different kinds of apparatus used for the preparation and examination of the specimens. These were followed by a large number of actual specimens depicted upon the screen in the most brilliant manner by means of the epidiascope, the details of surface and especially the coloration, being exhibited on a scale and in a manner impossible by any other means; the extremely beautiful colors produced by heating, and especially those upon a polished section of a meteorite, being amongst the finest examples exhibited.

Micrograms reproduced from the illustrations in Dr. Sorby's original papers clearly showed that as far as his work went, it was of a good and accurate character and that subsequent observations by more modern workers had confirmed all he had done.

In referring to the work of Osmond upon steel it was shown by his illustrations, and also by the work of the lecturer and other observers, that whilst the hardenite in steels quenched from a point a little above the recalescence point $Ar_{1\text{-}2\text{-}3}$, although crystalline, was practically amorphous, on heating to and quenching from a higher temperature, a crystalline structure was strongly developed and had the same characteristics as martensite in steels containing less carbon.

Troostite and austenite, although not thoroughly understood, had been recognized as true micro-constituents.

Sorbite, like troostite, required more study. It was neither troostite nor pearlite, and Osmond had described it tentatively as unsegregated pearlite. As much discussion had taken place during the last few years with regard to the nature of the micro-constituents, sorbite, troostite and austenite, a committee had been formed to work under Dr. Glazebrook, of the National Physical Laboratory, to endeavor to ascertain their true nature.

The work of Professor Arnold was illustrated by slides made from accurate drawings of the structures of cement steels and steels containing sulphur.

The lecturer expressed great appreciation for Arnold's drawings, and pointed out that in many cases they were preferable to photographs, but that generally photographs were better when properly taken.

The special features of Prof. H. Le Chatelier's work were illustrated by photomicrographs of cast irons and steels, some of the structures of which had been developed by the action of potash and lead oxide, which darkened the cementite but left the other constituents white.

The mid-ribs of cementite in the dark barbs of martensite were in this way clearly shown.

The effect of strain and continued reversals of stress on iron was illustrated by photomicrographs prepared by Prof. J. A. Ewing, Mr. Walter Rosenhain and Mr. Humphrey.

The surface flow of metals was illustrated by the elaborate work of Mr. G. T. Beilby.

The work of Mr. W. H. Merrett of the Royal College of Science was represented by photographs of granular pearlite magnified 1,600 diameters, which showed that the carbide of iron or cementite existed in globular or roughly-shaped globular particles completely separated from each other.

The micro-structures of steel produced by electrical processes were given by slides provided by Mr. F. W. Harbord, and shown to be identical with the micro-structures of steels made by the ordinary processes.

The structure of bronzes was very beautifully illustrated with slides provided by Messrs. C. T. Heycock and F. H. Neville, Cambridge. The lecturer, in describing the work of those gentle-

men remarked that the research upon copper and tin alloys presented to the Royal Society was of the highest merit, and a type of work such as students who wished to study metallic alloys should take as an example.

The Brinell System of Testing the Hardness of Materials.* — The method introduced by the Swedish engineer, Brinell, for testing hardness, consists in measuring the superficial area of the cavity formed in the sample by a ball of hardened steel (of the kind used for ball bearings) under the influence of a given pressure, the ball being half embedded in a backing plate of hard

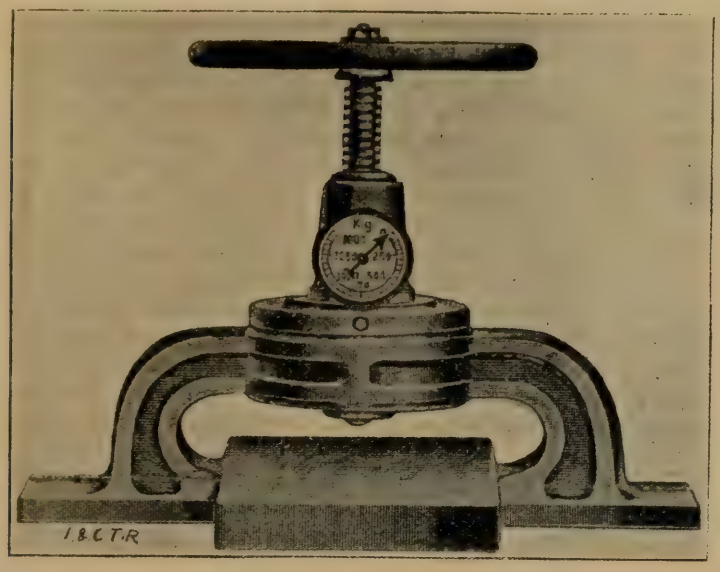


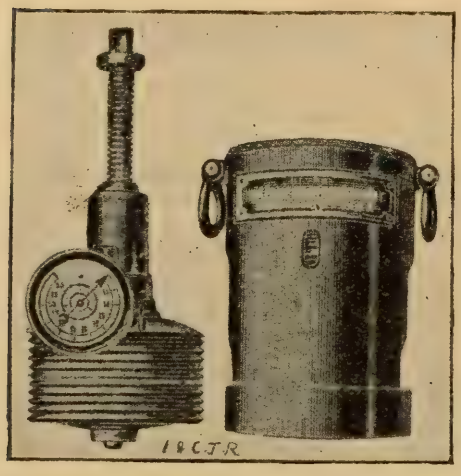
FIG. 1. Press for Pressures of 3 to 6 Tons

steel. On dividing the area of the cavity, expressed in square millimeters, by the pressure expressed in kilos, the resulting values give the "index of hardness" of the material under examination. It is found advisable to employ balls of one given size (10 millimeters in diameter) in order to obtain comparable results, and the margin of error may be still further reduced by making several impressions under different pressures, and selecting from these the one corresponding most nearly to a given standard area as the basis of calculation.

Apparatus for performing these tests is being put on the market by Mr. H. Huber of Höchst-on-Main. Fig. 1 represents

* "The Iron and Coal Trades Review," May 5, 1905.

a press giving pressures of 3 to 6 tons, and suitable for electricians, coppersmiths etc., for testing the hardness of copper collectors and other fittings. The pressure is recorded on the dial shown in the head of the press, and the ball has a maximum stroke of 2 inches. A larger form of the same press is made for testing objects of greater thickness, in which the stroke of the ball is 6 inches, the actual height above the base plate being adjusted up to 14 inches, according to the thickness of the test piece, by wheels and locking nuts on threaded pillars at either side of the frame.



FIGS. 2 AND 3. Apparatus for Higher Pressures, 60 to 100 Tons

Figs. 2 and 3 show the newest pattern for working with high pressures (60 to 100 tons). In this case the pressure apparatus is utilized direct for setting the ball at a level corresponding to the thickness of the sample under test. The pressure apparatus, Fig. 2, can also be combined with suitable attachments, such, for example, as that in Fig. 3, which is used in testing rails.

The measurement of the diameter of the impressed cavity is performed by the micrometer gauge illustrated in Fig. 4.

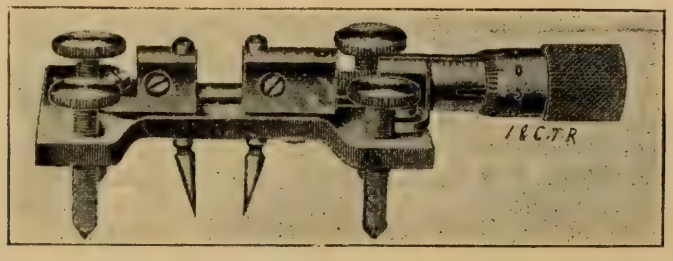


FIG. 4. Micrometer Gauge

This is placed on the test block and leveled by means of the four set screws until the gauge points just touch the surface of the material, the fixed point resting exactly on one edge of the cavity and the other one moved to and fro by turning the micrometer

screw, until it touches the other edge at a point diametrically opposite the former one. By this means the diameter of the imprint can be gauged to within the one one-hundredth part of a millimeter. A magnifying glass is employed to examine the position of the gauge points. By applying the results of this measurement to the apparatus represented in Fig. 5, the depth and angle of the cavity can be read off at once on the crossed scale without any calculation or reference to tables.

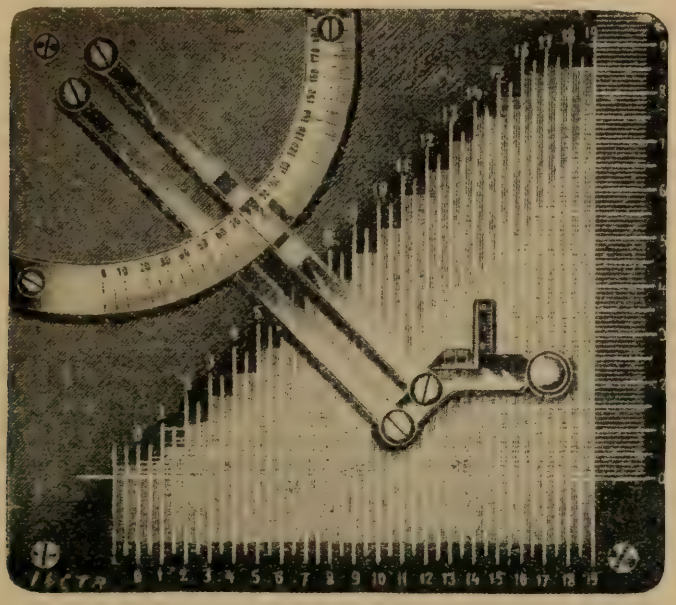


FIG. 5. Measuring Apparatus

One of the great advantages of this system of testing is that it can be applied to any finished article (*e. g.*, projectiles, steel plates, etc.) without any injury to the latter. On the other hand it is equally applicable to small test blocks or strips, there being no distortion of the material when the thickness of the latter exceeds one tenth of an inch, and the length and width are over $1\frac{1}{4}$ inches. Provided the test object is parallel on two sides and has one plane surface, it need not be trimmed to any particular shape nor even polished, though, of course, more accurate measurements can be made when this has been done.

The Exhaustion of Iron Ores

In his presidential address, delivered recently before the Institution of Mechanical Engineers, Mr. Edward P. Martin called attention to a question which, although of supreme importance to the manufacturing industries of this country, does not appear to be generally appreciated. This is the rapid exhaustion of not only our own best iron ores, but also of the most readily available foreign supplies. So serious a view does Mr. Martin take ot the outlook in this direction, that he considers it quite worthy of a Royal Commission for its thorough investigation. Nor is this view by any means extreme. The country is quite as dependent upon cheap iron as upon cheap coal for its industrial welfare. There was a time not so very long ago when the iron industry was absolutely dependent upon the joint occurrence of iron ore, fuel and limestone in close proximity to the works. Dowlais, in these early days, drew its supplies of these three essential materials from the same hillsides, where works were constructed for coking the coal, calcining the ore and smelting the iron. A period of more than a century, however has seen great changes in these favorable conditions. The Dowlias of to-day procures its fuel from some dozen miles away, and the bulk of the iron ore is imported from abroad.

Similar stories of altered conditions and exhaustion of the best ores can be told of other districts, and in face of this rapid depletion, the demand for steel and iron is continually increasing. Foreign ores of good quality, and within a reasonable distance, are by no means unlimited in quantity. Spain, although able at present to supply demands which are continually increasing, shows unmistakable signs that there is a limit to her resources. Scandinavia appears to have a more trustworthy reserve of high-class ores, but in spite of this advantage we should long before this have been in a very bad way had not the Thomas-Gilchrist process rendered it possible to make good steel from second-grade ores. It is for this reason alone that the important deposits of minette ores in French Lorraine, Luxemburg and Germany can now be counted as a valuable reserve.

Mr. Martin deals also with the rate of increase in the demand for pig iron. He recalls a prophecy of Mr. Abram S. Hewitt in 1872 that the world's production of pig iron in 1890 would reach 28,000,000 tons. The actual production for that year was 27,-

630,000 tons. At a similar rate of increase, in seventeen years' time the annual production of pig iron will be 80,000,000 tons, requiring 160,000,000 tons of iron ore, that is to say, about half as much again as the total production of iron ore in the Bilbao district for the past twenty-seven years.

What is the lesson conveyed by these figures? The old condition of close proximity of ore, fuel and flux has passed away. Even in the United States the proximity of one only of these requirements governs the location of steel works, and the difficulties arising out of the transport of the others are overcome by every conceivable device for minimizing the cost of freight and handling. In Great Britain we are already drawing supplies of ore not only from Spain and Scandinavia, but from Cuba, India, South America and New Caledonia, these latter, of course, being special varieties of ore for the manufacture of manganese and nickel steels. But this importation from distant countries is only now beginning. If we are going to continue to supply our growing markets in the future, there will not be an iron-ore deposit of good quality in any of our most distant colonies which will not be drawn upon for British blast furnaces.

Of course a check may be put upon the expansion of our markets. Some such action is said to be about to be taken in New South Wales. It is said that the government of that colony, in giving out railway contracts, is specifying that nine tenths of the material is to be of local production and manufacture. Should this course be adopted it might naturally be expected to result in the establishment of colonial steel works, and a corresponding restriction in British exports.

We imagine, however, that there are more difficulties in the way of establishing colonial steel works upon a commercial basis than can be overcome by so simple an expedient as a government bounty; for this is what the above-mentioned restriction would amount to. For very many years attempts have been made in India to manufacture steel and iron on a large scale, but progress in this direction is slow. It is probable, indeed, that the government of New South Wales will find it necessary to begin operations on a much more modest scale, and to build up gradually any local iron industry for which the country may possess natural facilities. Whatever, therefore, may be the ultimate condition of the colonial markets for

iron and steel manufactures, the coming phase promises to be marked by a growing demand for foreign and colonial ores for consumption in the blast furnaces of Great Britain. " The Colliery Guardian," April 28, 1905.

Limitation of Chemical Analysis. — The limitation of chemical analysis is well emphasized by some results recorded by Dr. Hans Goldschmidt, with respect to the effect of titanium on the strength of steel. In spite of practically the same chemical composition there is a distinct difference in the physical properties of the two samples when treated with titanium thermit or not. It is thus clear that to understand the subject, chemical analysis must be supplemented by microscopic investigation of the structure, and the results must be considered in the light of the theory of solid solutions, on the basis of Gibbs' and Roozeboom's views. However, the effect of the titanium-thermit treatment just noticed emphasizes another point. Here we have not simply the production of titanium-steel. (As a matter of fact we have yet not found any exact and clear-cut statement of the effect of the introduction of titanium into steel.) Dr. Goldschmidt carefully emphasizes that at least part of the effect of the titanium-thermit treatment is due to the mechanical stirring of the bath and the combination of nitrogen with titanium. For exactly the analogous reason, copper-silicon has long been used for copper castings, in order to combine with silicon the oxygen of the cuprous oxide dissolved in the copper. There is still another point. We know that the " occlusion " of gases may have an enormous effect on the physical properties of a metal; thus the extreme hardness of electrolytic iron was found by Prof. C. F. Burgess to be due to the occlusion of hydrogen in it. " Occluded " gases may play a similar important part in other metals. However, enough has already been said to indicate the great complication of the problem while the necessity of solving it is manifest. " Electro-chemical and Metallurgical Industry," June, 1905.

On the Utilization of Fine Ore, Flue-Dust, Downcomer-Dust and Stove-Dust, in the Blast Furnace. — At large furnace plants there accumulates vast quantities of these fine ores,— flue-dust, downcomer-dust and stove-dust,— hereafter to be referred to as

"fine materials." It is quite a problem and considerable expense to get rid of them. Especially is this the case in the Pittsburg, Youngstown and Lake districts, where the furnace burden is made up of from 40 to 75 per cent of Mesabi ores. Not only is this the case where Mesabi ores are used to a large extent, but also at other furnace plants where other ores and especially concentrates are used.

It has been no small problem for furnace managers to work these fine materials. Many methods have been tried to get these fine materials in a shape to be utilized in the furnace and at the same time have the mass porous, or at least in such a shape that when they descend with the furnace burden they will not prevent the passage of the blast and gases.

Briquetting has been tried and given considerable notoriety, especially with the New Jersey concentrates, but, so far as the writer has been able to learn, not a ton of these have been made the past two years. This, by the way, is not because the briquettes do not work well in the furnace, but because a ton of them has thus far cost more than a ton of pig iron has often sold for.

There is, however, I believe, one brilliant example of the briquetting process still in use, and that is, or was, at the Joliet plant of the Illinois Steel Company. At this plant they were elegantly fitted to carry on this work. The furnaces were run to produce a certain composition slag among other things, and this slag was manufactured into cement, and a part of the cement-making materials were utilized to incorporate with these fine materials, which were briquetted and dried and delivered to the furnace as a self-fluxing ore and formed a part of the regular furnace burden. They worked well and saved hundreds of tons of good fine materials which otherwise would have been wasted.

These fine materials are not inferior in chemical composition to ores from which they are derived; in fact, many of them are of considerably better composition. Analyses of these fine materials at the Buffalo Union Furnace Company show iron 62.50, lime 7, carbon 5 per cent. Recent analyses of these fine materials at the Port Henry plant of the Northern Iron Company, very kindly supplied by Mr. L. D. Fraunfelder, chemist and assistant superintendent, show theirs to run iron 51, lime 8.25 and carbon 4 per cent. These materials show, upon analysis,

that they are far too valuable to be thrown away. They are self-fluxing and carry a good percentage of carbon to partially reduce them.

Ore running from 50 to 62 per cent iron, on the dock at Buffalo, is worth from $3.50 to $4.50 per ton.

With a 50 per cent Mesabi mixture and the three furnaces running full blast there will be from 40 to 60 tons of these fine materials every twenty-four hours. Taking the average of 50 tons at $4.00, we have $200 worth of these fine materials per day.

It is useless to put them back in the furnace in their fine state, for they will come over at once with the blast if put in in small quantities, and if large amounts are filled at a time, they choke up the furnace, thus preventing the passage of the gases and causing the furnace to hang and slip.

The thing necessary then for the utilization of these fine materials is to incorporate them in something which will hold them until they get below the zone in the furnace where they can be carried over mechanically. Many materials have been tried and quite a number patented for bringing this about. The principal substances employed in the lumping process are glue, tar, molasses, asphalt, etc.

Working along these lines, the writer decided upon the idea of using carbon, or coking these fine materials with bituminous coal. The coal in coking thoroughly incorporates the fine materials, acting as a fairly good carrier, being porous, takes the materials down to the zone of reduction and much of it still further to the tuyères, carries more than enough carbon for reduction, carries no foreign materials into the furnace, and besides it is cheap. Samples have been made carrying 12½, 25 and 50 per cent by weight of these materials. The 25 per cent one, the mean, shows by analysis to run:

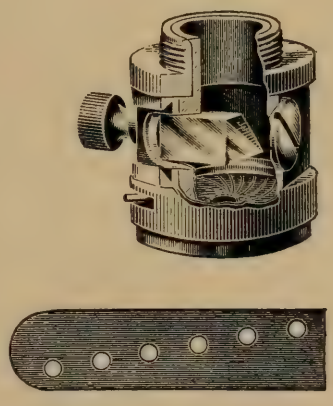
	Port Henry Per cent	Buffalo Per cent
Iron	14.07	16.51
Lime	2.35	2.11
Magnesium	0.30	0.70
Alumina	2.00	2.30
Fixed carbon	61.28	65.25
Volatile matter	10.56	6.86

These tests were conducted in a clay crucible. The process can be carried on very nicely in a bee-hive oven. A small battery

of these can be installed very reasonably and made to pay at a plant running four or more stacks. Any sized plant can be made to pay handsomely where the by-product ovens are used as they are at many plants to-day, and more are installing them. This plan is also applicable at any plant where the coke is made at or near the furnace.

I wish to acknowledge my indebtedness to Mr. L. D. Fraunfelder, chemist and assistant superintendent at Port Henry, N. Y., for his coöperation and analyses. James C. Attix, "Journal American Chemical Society," February, 1905.

A New Vertical Illuminator. — The accompanying illustration shows a vertical illuminator of the prism type, manufactured by Messrs. R. and J. Beck, Limited, London. The device is fitted with an iris diaphragm beneath the prism, for cutting off outside light, and a plate of stops so arranged that the position of the beam of light impinging on the prism can be varied until parallel light of the right angle is obtained. These vertical illuminators are used for the examination of metals and other opaque objects through the microscope.



New Southern Open-Hearth Steel Plant. — The Atlanta Steel Hoop Company, Atlanta, Ga., has recently placed contracts for a basic open-hearth steel plant, to contain two 35-ton basic open-hearth furnaces, with provision for a third. This will be the third steel plant in the South, the other two being the Ensley, Ala., plant of the Tennessee Coal, Iron and Railroad Company, ten 50-ton furnaces with an auxiliary Bessemer converter and a mixer, and the Gadsden, Ala., plant of the Alabama Steel and Wire Company, four 50-ton furnaces. The contract for the Atlanta plant is placed with the Wellman-Seaver-Morgan Company, of Cleveland. A contract has also been placed with the Morgan Construction Company, Worcester, Mass., for a Morgan continuous rod mill. The Atlanta company has been rolling hoops and cotton ties for several years from Pittsburg steel. Basic pig iron will be obtained from the Birmingham and Chattanooga districts, with a freight charge of less than a dollar a ton.

REVIEW OF THE IRON AND STEEL MARKET

The dullness in the iron trade so far as new buying is concerned has continued, and is even more pronounced than a month ago. Production has not suffered greatly. There has been a decline of possibly a couple of million tons in the annual production rate of pig iron from the high point, which was reached during May. While stocks of pig iron are in some cases uncomfortably large, the accumulation is rather small compared with the decrease in production, and it can hardly be said that production of castings and rolled forms has decreased from the maximum by as much as 3,000,000 tons a year.

The major part, if not all, of this decrease in production is taken care of, as regards ultimate consumption, by drawing upon the large stocks of merchant pipe, wire products, merchant steel bars, sheets and tin plates, which were accumulated in the winter and spring by jobbers and consumers. Actual consumption has not decreased much, if at all.

There is reason to believe, on these premises, that the lull in mill business will be only temporary. Of course there is no expectation that there will be a resumption of active buying before about the first of August, such a delay being natural on account of the time of year, but general business conditions are perfectly sound, and with reasonably good crops there is good ground for an expectation that the whole iron trade will open up in the fall under favorable auspices with greater activity and satisfactory prices.

The rail trade is alone in showing marked improvement. Recent orders for summer delivery have been so large that the Carnegie Steel Company has just concluded to change the Ohio mill, at Youngstown, from sheet bars and billets to rails. It had been the intention until this decision to roll no rails at the Ohio works this year. Further, the southern interest has taken 55,000 tons of orders for delivery next year, this indicating both confidence in the future and a desire on the part of the railroads ordering to be assured that they would get basic open-

hearth rails, the Alabama mill being the only maker of open-hearth rails on a large scale.

Pig Iron. — Since our last report there has been an obvious drop of about 50 cents in all grades of pig iron in the north, and of about $1.25 in southern pig. The actual drop may be larger, as the present market is one made by transactions involving small tonnages, representing, so far as large tonnages are concerned, only the nominal asking prices of furnaces. If large orders were offered it is simply impossible to say what prices furnaces would make. The total turnover has been very small, but consumers are taking deliveries fairly well on old contracts. Thus there has been little accumulation of foundry pig in western Pennsylvania and Ohio, while there has been a large accumulation of Bessemer pig, amounting, in the Mahoning and Shenango valleys, to perhaps 100,000 tons since May 1. The difference is that foundry pig is purchased more on long-time contracts than is the case with Bessemer, while the cessation of buying of outside Bessemer pig iron by the United States Steel Corporation has also had its effect. The last Corporation purchase was for April delivery, and no further purchases are likely in the present alignment of affairs, although sudden changes are not uncommon in this direction. The drop in southern pig iron has been spectacular, as a month ago $13 Birmingham was being quoted, against $13.50 ruling for a period of several months. There followed a drop to $12.75 and then, with scarcely any intermediate prices, the market has dropped to $11.75, with the possibility that still lower terms could be had on firm offers. We now quote prices as follows: F.o.b. valley furnace: Bessemer and basic, $14.75 to $15.00; No. 2 foundry, $14.75 to $15.00; gray forge, $14.25. Delivered Pittsburg: Bessemer and basic, $15.60 to $15.85; No. 2 foundry, $15.60 to $15.85; gray forge, $15.10. F.o.b. Birmingham: No. 2 foundry, $11.75 to $12.00; gray forge, $11.00 to $11.25. Delivered Philadelphia: No. 2 X foundry, $16.50 to $16.75; standard gray forge, $15.00 to $15.25. Delivered Chicago: Northern No. 2 foundry, $16.00 to $16.25; malleable Bessemer, $16.25 to $16.50. Freight Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65.

Steel. — The market is extremely quiet and has hardly declared itself; quotations being made are only on small lots,

and in the absence of inquiry for large lots and extended delivery it is impossible to say what could be done. On small lots quotations are about as follows: Soft steel billets, 4 x 4 and larger, $22.50 to $23.50, f.o.b. Pittsburg; sheet bars and small billets, $2.00 advance.

Shapes. — The structural mills continue extremely busy on specifications against old contracts, and cannot promise deliveries on new business for several months. Prices are unchanged at 1.60 cents for beams and channels 3 to 15 inch inclusive, angles 2 x 3 to 6 x 6 inclusive, and zees.

Plates. — There is not much new business in plates, but specifications on old contracts are excellent, so that all the large plate mills are very busy. Some small mills can make early shipments on new business, but the large mills take no interest in this class of trade. Prices are unchanged at 1.60 cents for plates over 14 inches and not over 100 inches wide, tank quality, quarter-inch and heavier, with the usual advances for other descriptions.

Merchant Bars. — The inquiries for steel bars for second half referred to in last report as coming from buyers who had contracts at 1.30 cents which expire July 1, have been adjusted by various means so that the buyers can get deliveries to October 1 at the same price. Really new business is quite light, and there has been a little more shading on the part of middlemen who had old contracts at lower figures, this in some cases extending to $2.00 a ton, although very small lots are only obtainable at the official price of 1.50 cents. Iron bars have been in better demand, prices having receded in harmony with the much lower figures on scrap. We now quote common iron bars at 1.55 to 1.60 cents, Pittsburg, and 1.50 to 1.55 cents, delivered Chicago.

Sheets. — Demand from mills is fairly good, while consumption is larger than would be thus indicated, as the large stocks accumulated in the winter and spring are being heavily drawn upon. There is no further weakness, the official prices of 2.40 cents on black and 3.45 cents on galvanized, No. 28 gauge, being shaded from $1.00 to $2.00 per ton for carload and larger lots.

Scrap. — The scrap market has been very quiet, but prices have been more settled in the past fortnight, and can be quoted

approximately as follows, for Pittsburg and nearby delivery: Heavy melting stock, $14.00 to $14.50; sheet scrap, $12.50 to $13.50; old car wheels, $15.00 to $16.00; cast borings, $8.00 to $8.50.

STATISTICS

The Iron and Steel Industry in 1904. — The general summary of statistics for 1903 and 1904 shown on the following page is reproduced from Mr. James M. Swank's admirable report presented to the members of the American Iron and Steel Association on June 10, 1905. The following interesting comments are also from Mr. Swank's general review of the American iron trade.

"The improvement in general trade conditions has particularly affected the iron trade, so much so that for several months the demand for iron and steel products in this country has never been equaled. It has taxed and is still taxing our manufacturing plants to their utmost available capacity. This extraordinary activity is probably of more general application to all branches of the iron trade than any similar demand in other years. Certainly our manufacturers of pig iron, steel rails, structural steel, plates and sheets, cars and locomotives (including railroad shops), and general machinery and foundry products were never more actively employed than they are to-day. The whole country urgently wants iron and steel for a thousand uses. Our export trade in some iron and steel branches is also contributing to the general activity. But the greatest demand for iron and steel comes from the railroads. The fact is now generally recognized that our railroad managers have not kept abreast of the country's marvelous industrial development in the last few years. More tracks, more cars and more locomotives have been needed than have been built, and also more bridges and better terminal facilities. Some of these managers awakened to the necessity of meeting these deficiencies before the general revival of prosperous conditions last year, but others did not awaken to the needs of their roads until the present year, and it is to the suddenness of this awakening that we owe much of the existing unprecedented demand for iron and steel."

SUMMARY OF STATISTICS FOR 1903 AND 1904.

Subjects—Calendar years.	1903.	1904.
Production of Iron Ore, gross tons	35,019,308	27,600,000
Imports of Iron Ore, gross tons	980,440	487,613
Production of Bituminous Coal, gross tons	252,454,775	249,102,765
Production of Pennsylvania Anthracite, gross tons	66,613,454	65,318,490
Production of all kinds of Coal, gross tons	319,068,229	314,421,255
Shipments of Pennsylvania Anthracite, gross tons	59,362,831	57,492,522
Imports of Coal for Consumption, gross tons	3,479,430	1,623,280
Domestic Exports of Coal, gross tons	8,312,098	8,573,518
Production of Coke, net tons	25,262,360	23,621,520
Production of Pig Iron, gross tons	18,009,252	16,497,033
Production of Spiegeleisen, Ferro-manganese, and Ferro-phosphorus, included in Pig Iron, gross tons	192,661	220,392
Production of Bessemer Steel, gross tons	8,592,829	7,859,140
Production of Open-Hearth Steel, gross tons	5,829,911	5,908,166
Production of Crucible Steel, gross tons	102,434	83,391
Production of Blister and Patented Steel, gross tons	9,804	9,190
Production of all kinds of Steel, gross tons	14,534,978	13,859,887
Production of Open-Hearth Steel Castings, gross tons	400,348	302,834
Production of all kinds of Steel Castings, gross tons	430,265	330,211
Production of Bessemer Steel Rails, gross tons	2,946,756	2,137,957
Production of Open-Hearth Steel Rails, gross tons	45,054	145,883
Production of Iron Rails, gross tons	667	871
Production of all kinds of Rails, gross tons	2,992,477	2,284,711
Production of Structural Shapes, gross tons	1,095,813	949,146
Production of Iron and Steel Wire Rods, gross tons	1,503,455	1,699,028
Production of Plate and Sheet Iron and Steel, except Nail Plate, gross tons	2,599,665	2,421,398
Production of Bar, Bolt, Hoop, Skelp, Rolled Axles, Rolled Armor Plate, etc., gross tons	4,952,185	4,597,497
Production of all Rolled Iron and Steel, including Nail Plate and excluding Rails, gross tons	10,215,220	9,728,670
Production of all Rolled Iron and Steel, including both Nail Plate and Rails, gross tons	13,207,697	12,013,381
Production of Iron and Steel Cut Nails and Cut Spikes, kegs of 100 pounds	1,435,893	1,283,362
Production of Iron and Steel Wire Nails, kegs of 100 pounds	9,631,661	11,926,661
Production of Tinplates and Terne Plates, gross tons	480,000	458,000
Production of Ore, Pig, and Scrap Blooms for sale, gross tons	9,940	5,743
Imports of Iron and Steel, foreign value	$41,255,864	$21,621,970
Exports of Iron and Steel, home value	$99,035,865	$128,553,613
Miles of New Railroad built (estimated for 1904)	4,715	4,252
Tonnage of Steel Vessels built in the calendar year	295,840	160,809
Immigrants in the year ended December 31	937,371	808,967

RECENT PUBLICATIONS

The Chemistry of Gas Manufacture, by W. J. Atkinson Butterfield. Third edition, revised. Volume I, Materials and Processes. 257 5 × 7½-in. pages; 31 illustrations. Charles Griffin & Co. London. 1904. — In the third edition of this well-known work it has been decided to publish it in two volumes, the present one dealing with materials and processes and a second volume in active preparation which will deal with the analysis, testing and uses of gas. Volume I is divided into seven chapters dealing respectively with the Raw Materials of Gas Manufacture, Coal Gas, Carbureted Water Gas, Oil Gas, Enriching by Light Oils and Final Details of the Manufacture and Sundry Schemes for Making and Enriching Gas. There is at the present time a steadily increasing interest on the part of engineers and others in the important subject of the manufacture of gas and in the best methods of using it, and the practical book we have before us should prove of much interest and value.

Lehrbuchder Mechanisch Metallurgischen Technologie, Zweite abteilung, by A. Ledebur. 400 4 × 6-in. pages; over 300 illustrations. Paper covers. Friedrich Vieweg & Sohn. Braunschweig, Germany. 1905. Price, $4.25. — This is the second and concluding volume of Professor Ledebur's masterly description of machine shop and other mechanical operations to which metals are subjected, the first volume having been reviewed in our issue for April, 1905. This treatise will undoubtedly be classed among the best of German technical publications both because of the value of the contents and the high degree of excellence of its typography and illustrating.

Electric Smelting and Refining, by Dr. W. Borchers. Translated from the third German edition, with additions by Walter G. McMillan. Second English edition. 562, 5½ × 8½-in. pages; 254 illustrations. Charles Griffin & Co. London. 1904. Price,

$7.00. — Electric smelting is daily becoming of greater importance, and engineers and metallurgists are fully aware that hardly more than an entering wedge has been driven in this wonderfully promising field. Dr. Borchers is one of the most authoritative writers on the subject of electro-chemistry and this excellent translation of his important work should be welcomed by the increasing number of persons interested in the electric smelting and refining of metals. The first part of the book containing 92 pages is devoted to alkalies and alkaline earth metals; the second, containing 90 pages, to the earth metals; and the third, covering 362 pages, to the heavy metals. The addenda which follows contain two valuable tables, one showing the value of equal current volumes, as expressed in amperes, per square decimeter, per square foot and per square inch of electrode surface; the other shows comparison of Centigrade and Fahrenheit thermometer scales.

The book is well printed and finely illustrated.

Jahrbuch für das Eisenhüttenwesen (Year Book of the Iron Industry), supplementary to "Stahl und Eisen," by Otto Vogel. Third year. 465 6 × 9-in. pages; illustrated. Semi-flexible covers. A. Bagel. Düsseldorf, Germany. 1905. Price, 10 marks. — This volume gives an account of progress in all departments of the iron and steel industry during the year 1902. It contains indexes of authors and of matter covering 40 pages. The subject is so divided and subdivided as to make quick reference possible, and the original source of all articles is carefully given. The value of this yearly publication is not to be denied but we think that this would be greatly enhanced if subsequent volumes could be issued more promptly.

Jahrbuch der Elektrochemie für 1903, by Heinrich Danneel. 930 6½ × 9½-in. pages; 137 illustrations. Paper covers. Wilhelm Knapp. Halle-a-S., Germany. 1905. Price, $8.50. — This is the tenth yearly volume of a publication of growing importance. It consists of intelligent and critical abstracts of all papers and articles of value which have appeared in 1903 in nearly one hundred periodicals. The first part is devoted to the theoretical side of the science, the second part to applied electrochemistry. It also contains an index of authors of 38 pages and

an index of matter of 44 pages. It is unnecessary to insist upon the value of such work to all students of electro-chemistry and its applications. It could hardly be overestimated. Our only regret is that it does not also appear in the English language. The volume is finely printed and illustrated.

Metallurgie du Zinc, by A. Lodin, chief engineer of mines and professor of metallurgy in the School of Mines, Paris. 810 6 × 9½-in. pages; 275 illustrations and 25 plates. Paper covers. Vve. Ch. Dunod. Paris. 1905. Price, 35 francs. — So voluminous a book on the metallurgy of zinc suggests exhaustiveness, and the name of its author is a guaranty of authoritative and clear treatment. The first chapters deal with the occurrence of zinc in nature, the following ones with the preliminary treatments such as roasting and calcining, while the last chapters, forming the bulk of the work, are devoted to the melting and distillation of zinc. Recent attempts to do away with the retort treatment of zinc are discussed by the author. By publishing such a satisfactory treatise of the technology of zinc metallurgy the author has contributed a most valuable addition to the metallurgical art.

Gas Engines and Producer Gas Plants, by R. E. Mathot. Translated from the French by Waldemar B. Kæmpffert, with a preface by Dugald Clerk. 314 6 × 9-in. pages; 152 illustrations. The Norman W. Henley Publishing Company. New York. 1905. Price, $2.50. — Gas engines and producer gas plants are attracting the earnest attention of an increasing number of engineers. The progress made in recent years in the construction and running of gas engines is a notable one and augurs well for the future of this apparatus. The translation of Mr. Mathot's able book should therefore prove of value to many. Mr. Dugald Clerk in his preface highly commends the author's treatment of his subject. "I know of no work," Mr. Clerk writes, "which has gone so fully into the details of gas-engine installation and up-keep. The work clearly points out all the matters which have to be attended to in getting the best work from any gas engine under the varying circumstances of different installations and conditions. In my view the book is a most useful one, which deserves, and no doubt will obtain, a wide public recogni-

tion." The book is printed in large type, on good paper and is well illustrated.

Properties of Steel Sections, by John C. Sample. 121 6 × 9-in. pages; illustrated. McGraw Publishing Company. New York. 1905. Price, $3.00. — This is a reference book for structural engineers and architects, including tables of moments of inertia and radii of gyration of built sections, examples of sections selected from monumental structures, unit stresses, safe loads for columns, plate-girder designs, design in timber, etc., with only sufficient text to explain their application. The useful character of the book will be readily appreciated, the aim of the author being to assist the designer in submitting on short notice, by selection from his tables, designs which would otherwise call for laborious calculations.

Metal Working, by Paul N. Hasluck. 760 6½ × 9-in. pages; 2,200 illustrations. Cassell & Co. London. Price, 9 shillings. — The character of this book is thus described in the preface: "The scope of this book embraces practically the whole art of working metals with hand-tools and with such simple machine-tools as the small engineering shop usually contains. The tool outfit of the average metal worker does not generally include anything more ambitious than a lathe with or without slide-rest, overhead motion, etc., and it is with this limitation in mind that the whole of the contents of this book have been prepared. Even within such limits, the scope is extensive, and has been made to include a large and pleasing variety of work."

Constitution of Hydraulic Mortars, by Henri Le Chatelier. Translated from the French by Joseph Lathrop Mack. 132 6 × 8-in. pages; illustrated. McGraw Publishing Company. New York. 1905. Price, $2.00. — This book is the translation of a thesis for the doctor's degree presented by Mr. Le Chatelier some fifteen years ago but brought up to date by a number of notes describing the later advance in our theoretical knowledge of cements. As the author rightly says, his thesis has been the starting point of numerous studies, and although written comparatively long ago, it retains much importance for those interested in cement and mortars.

This late English translation should, and undoubtedly will, receive a warm welcome. The translator justifies it in the following words: "His classic work (Le Chatelier's) therefore stands to-day as the first, the most complete and beautiful piece of work done upon the chemistry of Portland cement, and since the original is not easily obtained and all later work on this subject goes back to and rests upon this thesis, I have thought that it ought to be available to all who are interested in the manufacture and use of Portland cement." The book is well printed and attractively bound.

Cement and Concrete, by Louis Carlton Sabin. 507 6 × 9-in. pages. McGraw Publishing Company. New York. 1905. Price, $5.00. — This work is divided into four parts as follows: Part I, Cement: Classification and Manufacture; Part II, Properties of Cement and Methods of Testing; Part III, The Preparation and Properties of Mortar and Concrete; Part IV, Use of Mortar and Concrete. The author describes in his book the most advanced methods of using cement in construction, and the original investigations forming the basis of the work were made in connection with the construction of the Poe Lock at St. Mary's Falls Canal, Michigan. The book is well printed on good paper, and attractively and substantially bound.

The Modern Asphalt Pavement, by Clifford Richardson, director New York Testing Laboratory, Long Island City, N. Y. 580 6 × 9-in. pages; 32 illustrations. John Wiley & Sons. New York. 1905. Price, $3.00. — The author states in his introduction that the object of this book is to demonstrate the nature of asphalt pavements and the causes of defects in them, to bring about improvement in the methods of their construction, and to show how this can be done. The forms of construction which have been shown by experience to be the most satisfactory are fully described, as well as the character of the material entering into the composition of asphalt pavements, the most refined methods used in the industry at the present day and the reasons which have led to their adoption, in order that engineers and others who are responsible for the supervision and character of such work may be able to distinguish between that of good and that of inferior quality. To this is added specifications

for asphalt pavement to meet various environments and uses, and something as to their maintenance and the causes of their deterioration. The book is well printed and bound.

The Manufacture of Hydraulic Cements, by Albert Victor Bleininger. 391 6½ × 9-in. pages; 81 illustrations. Geological Survey of Ohio. Fourth series, Bulletin No. 3. Columbus, Ohio. 1904. Price, 50 cents. — In his announcement Mr. Edward Orton, state geologist, writes that it has been his intent and desire in authorizing and supervising the preparation of the volume to place within the reach of every intelligent person who desires it, a statement of what materials are needed to make good cements, what mechanical treatment is necessary, and what effects will result from deviations from the prescribed quality of materials or treatment. In his letter of transmittal he states that this bulletin represents almost four years of unflagging and enthusiastic labor, and he expresses the belief that it is a contribution to knowledge the importance of which will be promptly recognized. We shall only venture a minor criticism, namely, regarding the repeated and jarring reference to Le Chatelier as Chatelier. The prefix "Le" before French names is just as much a part of the name as the prefix "Mac" before some English name, and who would think of calling Mr. McIntosh Intosh. The lack of culture it implies verges on offensiveness.

Electrician's Handy Book, by T. O'Conor Sloane. 761 4½ × 6-in. pages; 556 illustrations. Flexible covers; gilt edged. The Norman W. Henley Publishing Company. New York. 1905. Price, $3.50. — From the publishers' announcement we extract the following information concerning the scope of this book:

"It is designed to cover the field of practical electric engineering, yet to include nothing unnecessary for the every-day worker in electricity to know. Its pages are not encumbered with any useless theory, everything in it is to the point, and can be readily understood by the non-technical man, and at the same time the educated engineer will receive great benefit from its perusal. The Electrician's Handy Book, with its résumé of the field of electric engineering, and its logical presen-

tation of the essentials of the science is a library in itself and supplies this need."

The magnitude of Mr. Sloane's work and its great usefulness are not to be denied. Reference books of this nature, when well prepared, are invaluable to workers in applied science. The publishers also have done their part most satisfactorily in issuing the book in a convenient size, well printed and illustrated and suitably bound.

Annual Report of the Smithsonian Institution, 1903, *United States National Museum*. 647 6 × 9-in. pages; numerous illustrations. Government Printing Office. Washington. 1905. — This last report of the National Museum of the Smithsonian Institution contains (1) the assistant secretary's report with appendices and (2) papers descriptive of museum buildings. The illustrations are of the usual high degree of excellence.

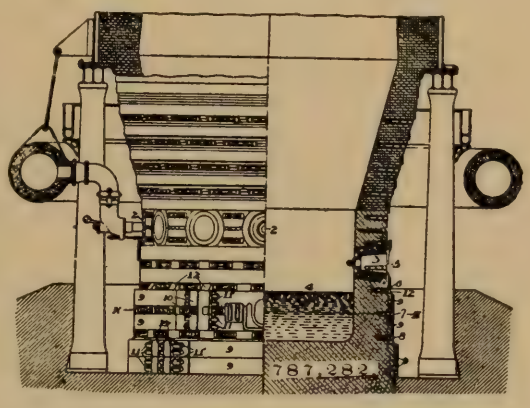
Contributions to Economic Geology. United States Geological Survey. 1904. Bulletin No. 260. 620 6 × 9-in. pages. Government Printing Office. Washington. 1905.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

787,282. Means for Protecting Blast-Furnace Hearths. — Charles E. Dinkey and Hermann A. Brassert, North Braddock, Pa. A blast furnace having a hearth wall provided with circular rows of separated holes extending horizontally and inwardly from its outer vertically extending face below the level of the cinder notch, and water-cooled plates arranged in series in said holes, the outer vertically extending face of the masonry wall being exposed and accessible between the sides of the plates, and separated horizontal retaining-bands between the rows, the hearth wall being free from any inclosing jacket.



787,612. Method of Shaping Metallic Ingots by Transverse Rolling. — Leonard D. Davis, Erie, Pa. A method or process of shaping metallic ingots, which consists in first piercing the ingot with a relatively small opening, and smoothing and compacting the walls of the opening so made, and then transversely rolling the ingot without axial movement of the ingot so pierced for shaping its outer surface.

787,758. Process of Treating Products Containing Vanadium, Molybdenum, Titanium and Tungsten. — Henri L. Herrenschmidt, Le Genest, France. A process of treating ores or products containing vanadium for the purpose of obtaining vanadic acid, the same being characterized by the following operations: the refining of a vanadate-of-soda liquor by evaporation and crystallization; the precipitation of the vanadium contained in the purified liquor by the action of concentrated sulphuric acid upon said liquor, previously concentrated to a syrupy condition; and the process of reduction by a reducing agent.

787,770. Process of Manufacturing Fire-Bricks, Crucibles, Retorts or other Refractory Articles. — Paul Klein, Riga, Russia. A process for manufacturing refractory articles, consisting in pulverizing chrome ore, separating the easily fusible admixtures therefrom, mixing the chrome ore thus obtained with pulverized fire-clay and with pure hydrate of alumina, molding and pressing and then burning such mixture.

787,926. Process of Treating Iron, Cast Iron and Steel. — Jean Lecarme, Paris, France. The process of hardening and transforming into steel of variable qualities the entire or part of the surface of objects, rotary cutters, screw-taps and other tools, and bells and other sonorous instruments made of iron, cast iron or mild steel, said process consisting of coating the objects on the surfaces or parts to be treated with a composition containing charcoal in powder, cyanide of potassium and a combustible agglutinant body, and then heating these bodies to a bright red excluded from the air.

788,767. Process of Coloring Steel or Iron Plate. — Thomas O'Brien and William P. Long, Elwood, Ind., assignors to American Sheet & Tin Plate Company, Pittsburg, Pa. That method of coloring metal sheets which consists in heating the same in a closed receptacle, reducing the temperature of the receptacle and sheets, and thereafter introducing an oxidizing liquid into the receptacle while the plates are hot and the cover remains over the sheets.

788,334. Apparatus for Casting Metal. — James Scott, Pittsburg, Pa., assignor to American Casting Machine Company, Pittsburg, Pa. In casting apparatus, the combination with two or more adjacent sets of molds, having mechanism for moving them, of an intermediate casting-pot provided with a well, and troughs integral with and leading from it, and means for tilting the pot, whereby the liquid metal may be directed into either set of molds, or in equal or varying streams into both sets.

788,339. Ingot-Stripping Apparatus. — Clarence L. Taylor, Alliance, Ohio, assignor to the Morgan Engineering Company, Alliance, Ohio. In an ingot-stripper, the combination with a hollow rack-bar carrying tongs, and a screw within the bar, of a plunger also within the bar and carrying a nut which engages the screw and means for rotating the screw.

788,378. Gas-Producer. — Josef Reuleaux, Wilkinsburg, Pa., assignor to Alexander Laughlin, Sewickley, Pa. A gas-producer having an air-distributor located centrally of the fire-bed, an air-heating chamber surrounding the producer, and a series of lateral branches connecting the chamber and the distributor, said chamber and branches being constructed so as to contain a body of water.

788,650. Continuous Process of Manufacturing Steel. — Henry Knoth, Birmingham, Ala.

788,778. Process of Case-Hardening. — Carlo Lamargese, Rome, Italy.

788,813. Process of Treating Fine Ores. — David Baker and William W. Hearne, Wayne, Pa.

788,888. Apparatus for use in Uniting Iron and Steel Plates. — William Cross, Winnipeg, Canada.

788,964. Casting Apparatus. — Edward A. Uehling, Passaic, N. J.

789,133. Apparatus for Distributing Molten Slag in Blast Furnaces. — Ralph Baggaley, Pittsburg, Pa., and Charles M. Allen, Lolo, Mont.; said Allen assignor to said Baggaley.

788,934. Manufacture of Expanded Metal. — George G. McKay, Youngstown, Ohio, assignor to Youngstown Iron and Steel Roofing Company, Youngstown, Ohio.

789,135. Apparatus for Charging Furnaces. — Ralph Baggaley, Pittsburg, Pa.

789,160. Apparatus for Feeding and Distributing Molten Material in Blast Furnaces. — Edward W. Lindquist, Chicago, Ill., assignor to Ralph Baggaley, Pittsburg, Pa.

789,298. Rolling-Mill Feed Mechanism. — Edwin E. Slick, Pittsburg, Pa.

789,767. Apparatus for Charging Plates into Furnaces. — George T. Snyder, McKeesport, Pa., assignor to National Tube Company, Pittsburg, Pa.

789,828. Ingot-Mold. — Thomas D. West, Sharpsville, and George H. Boyd, Sharon, Pa.

789,844. Art of Controlling Furnace-Gases. — John W. Dougherty, Steelton, Pa.

790,202. Method of Manufacturing Castings. — Jacob K. Griffith, Latrobe, Pa.

790,269. Furnace-Wall Construction. — David Baker, Newton, Mass.

790,270. Casting-Machine. — David Baker, Newton, Mass.

790,271. Charging Mechanism for Blast Furnaces. — David Baker, Newton, Mass.

790,392. Process of Producing Ferro-Chromium. — Edgar F. Price, Niagara Falls, N. Y.

790,393. Process of Smelting Iron Ores and Producing Ferro-Chromium. — Edgar F. Price, Niagara Falls, N. Y.

790,395. Process of Producing Low-Carbon Metals or Alloys. — Edgar F. Price, Niagara Falls, N. Y.

790,396. Process of Producing Low-Carbon Metals or Alloys. — Edgar F. Price, Niagara Falls, N. Y.

790,397. Process of Producing Low-Carbon Metals or Alloys. — Edgar F. Price, Niagara Falls, N. Y.

790,435. Process of Compressing Metal Ingots. — Robert W. Hunt, Chicago, Ill.

790,544. Casting Apparatus. — William S. Weston, Chicago, Ill.

790,545. Casting Apparatus. — William S. Weston, Chicago, Ill.

GREAT BRITAIN

5,648 of 1904. Making Slag Wool. — J. H. W. Stringfellow, London. Improved mechanical devices for producing slag wool and fertilizers from blast-furnace slag.

19,053 of 1904. Basic Converter. — O. Massenez, Wiesbaden, Germany. Modification in the basic Bessemer process, whereby the silicon is first eliminated and the slag poured off and afterward the phosphorus eliminated.

9,110 of 1904. Open-Hearth Furnace. — B. Talbot, Leeds. In open-hearth furnaces, making several hearths one after the other so that the heat and oxides contained in the slag on the finished metal on one hearth is utilized for refining the metal in the next by causing it to boil over the separating bridge.

9,482 of 1904. Refining Iron. — J. B. Nau, New York, U. S. A. In refining iron by the admixture of ores, methods for keeping the ores in thorough contact with the iron and not merely floating on top.

7,478 of 1904. Binder for Iron Ore Briquettes. — T. Rouse and H. Cohn, London. Use of alum and water glass as binding mixture for making briquettes of fine iron ores.



PAUL LOUIS TOUSSAINT HÉROULT

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The Iron and Steel Magazine

". . . . . Je veux au mond publier
d'une plume de fer sur un papier d'acier."

Vol. X August, 1905 No. 2

SOME CAUSES OF FAILURE OF RAILS IN SERVICE *

ROBERT JOB, Chemist, Philadelphia & Reading Railway

FOR a number of years a careful study of causes of rail failures has been made by the Philadelphia & Reading Railway. The method followed has been, in the case of each failure, to forward a portion of the rail showing the defective condition to the Test Department, with a form giving information regarding the manufacture and service of the rail. An investigation then followed to determine the cause of the failure.



In a general way it may be said that when failure occurs owing to fracture, excessively rapid rate of wear under given conditions, or crushing down in track, the poor service is generally due to one or more of the following causes, viz.: (1) Pipes in the steel, (2) presence of a considerable proportion of blowholes, (3) excessive segregation, (4) coarse granular structure, (5) rough handling.

* Read at the July, 1905, meeting of the American Society for Testing Materials.

In the first case the defect is readily shown by the appearance of the fractured end with its unwelded surfaces, and, upon buffing off a section of the rail, the extent of the pipe is generally clearly shown, even without etching, as in Fig. 1. In such case the steel is in a seamy condition, and the layers readily split apart or crush down upon comparatively slight pressure, and indication of the unsoundness is usually given after a very short service. This general type is caused by failure at the mill to crop ingots down to sound steel, and such a rail is nearly always derived from metal from the top of an ingot, and almost invariably fails when tested under the drop test. When the



FIG. 1. Pipe in Steel. Section polished but not etched

mill inspection is watched closely and when it is seen that the test butt for the drop test is always taken from the top of the ingot, failures due to such pipes are relatively rare.

A defect of this character is one of the most dangerous which can be present, since it is liable to result in sudden crushing under light pressure, and consequently it should be guarded against most carefully at the inspection.

The second cause of failure, viz., presence of considerable proportion of blowholes in the steel, is probably the most common defect under present mill practice, and the one which causes the largest number of failures in service to-day.

Such rails usually do not fracture after a very short service unless the extent of the blowholes is very pronounced, but the defects are generally noticed by the gradual mashing down of portions of the rail, accompanied generally by flowing over at the sides of the head, and the track men are apt to complain that the rail in question is " too soft," or that it has numerous " soft spots."

Analysis proves, however, that the metal is not softer than that in other rails adjoining the defective one, but upon polishing and etching the section lightly with iodine or other medium it will be found that the steel is unsound, or, in other words,



FIG. 2. Wing Rail. Unsound steel; five weeks' service

that blowholes, slag, and other foreign matter have prevented thorough welding of the steel and have resulted in a number of seams which break up the solidity of the metal and permit a slipping apart of the unwelded surfaces under moderate pressure, causing final fracture or crushing. In some cases this condition is caused by presence of slag and of oxides in the steel, but in the greater number of instances it is simply due to blowholes, and relatively little slag or oxide is present.

Fig. 2 represents the heel of a wing rail of a frog of the following analysis:

Carbon	.63 %
Phosphorus	.137
Sulphur	.078
Manganese	.874

This rail crushed down in service upon another road into the condition shown in less than five weeks.

Figs. 3 and 4 represent a batch of rails which mashed down in a few months upon another road to the contour represented by the dotted line. The unbroken line represents the template, and the large black areas indicate holes in the steel which were formed by the elongation of the metal upon the top of the rail when the failure began.

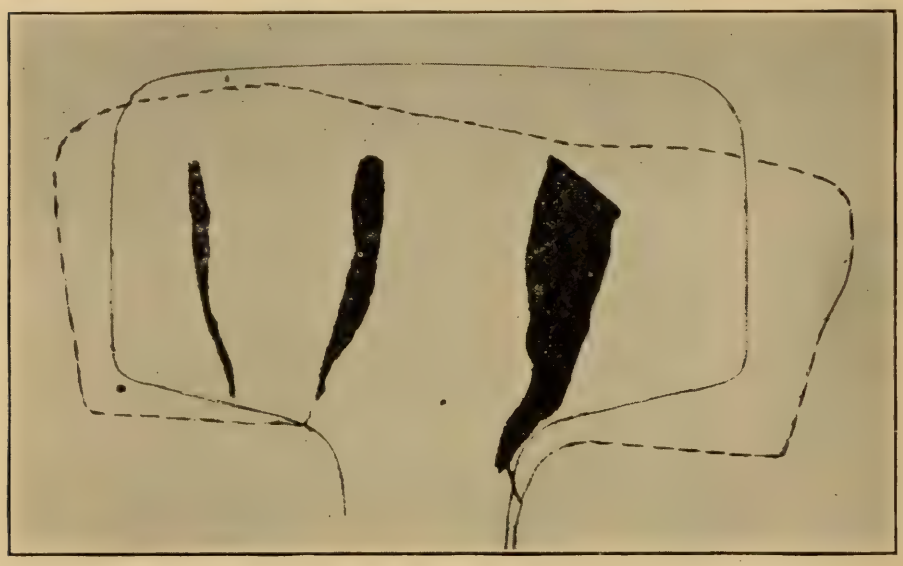


FIG. 3. Contour of Fig. 4 after service of five months

When this section was polished there was no indication of an actual pipe, but upon light etching the cause of the weakness is very evident, showing that the steel is so thoroughly unsound and porous that rapid crushing was possible.

The composition of this rail was:

Carbon	.82 %
Phosphorus	.102
Manganese	.88
Sulphur	.053

and the heat average was:

Carbon	.59 %
Phosphorus	.075
Sulphur	.074
Manganese	1.06

It is thus seen that a marked segregation was present, as well as great unsoundness, and it is evident that the cropping at the mill had been insufficient to get to sound and reasonably homogeneous metal. These rails were furnished under the mill's own specifications and guaranty.

The tendency of some rails to flow over and form a "lip"



FIG. 4. Unsound Steel; five months' service

has been referred to, and this frequently is attributed to mere softness of the steel. Our experience has been that a rail with carbon as low as even 0.33 per cent will not flow over under exceedingly heavy traffic, provided sound steel is present, with granular form fine enough to render the metal tough and strong; and in every instance of flowing over or of breaking down of the side or corner of the head, we have found presence of blowholes or other unsoundness near the surface or corners of the head of the rail, generally within one eighth or one quarter of an inch of the surface, whereas in the cases in which the rails have sustained long and heavy traffic, we have found comparative

freedom from such defects. A case of this kind which was investigated a couple of years ago will illustrate the point.

A number of rails from a single rolling had mashed down in track after two months' wear, to the general form represented by Fig. 5, the broken line representing the template. These defective rails were upon curves and upon tangent, and were from various heats throughout the rolling; but rails from the same heats and immediately adjoining the defective rails were unaffected by the traffic.

It was found that composition had nothing to do with the failures, but upon polishing and etching the sections we found, in the cases in which flowing and splitting occurred, that



Fig. 5. Contour of Fig. 6; two months' service

the steel was unsound, as indicated in Fig. 6, while the rails adjoining, which were in good condition, were of sound steel, as indicated in Fig. 7.

We have also investigated a considerable number of rails to determine whether or not the form of section exerted an influence upon the tendency to crush in service, and it has been clearly proved that ability to withstand crushing under heavy service is due not so much to any particular form of section, as to the relative freedom from unsoundness in the metal. In connection with this question an examination was made about a year ago upon a lot of rails which were removed from main track and relaid in branch lines. The section had a rather deep

head, with contour approximating that of a wheel flange. Practically no flowing and no crushing was found in these rails after fifteen years' service, while a number of rails of the American Society section laid in adjoining parts of the same track had crushed and otherwise failed in a very few years. The composition of the different lots showed comparatively little variation, but in the case of the rails which crushed in service we invariably found unsoundness, of the general type indicated by Fig. 6, whereas in the good rails the steel was practically sound within one-half inch of the surface of the top and sides of the head. In



FIG. 6. Unsound Steel; two months' service.
Mashed down as shown in Fig. 5

other words, the good service was due mainly to the greater care exercised in the manufacture of the earlier rails and their consequent relative freedom from unsoundness.

Up to this point we have made little mention of granular structure of the metal, and it may be inferred that this has little influence upon the permanency of the rail in track. On the contrary, we have reason to regard a uniform fine granular structure of high importance, both in reducing rate of wear and in cutting down liability of fracture, but it is an unfortunate fact that the very best of steel as regards granular form or com-

position may be completely and quickly ruined, from the standpoint of efficiency in track, or, in other words, as to its value as a rail, by failure in manufacture to insure reasonable freedom from unsoundness. This, to our mind, is an integral point in the manufacture of rails, for if any material degree of unsoundness exists in the rail within a distance, say, of one quarter or one half an inch from the head or sides, and more particularly near the upper corners, unsatisfactory service under heavy traffic is almost certain to result, regardless of the composition



FIG. 7. Sound Steel; two months' service. Rail next in track to Fig. 5. No tendency to mash down or flow over

or method of rolling. Such, at least, has been our invariable experience.

As to injurious segregation, we find that relatively few failures in track are due to this condition. If ingots are not properly cropped, or if they are allowed to remain in the furnace with the interior of the ingot in a liquid condition for an excessive time, segregation, of course, results, and if the test butt from each heat is taken, as should invariably be done, from the top of the ingot, badly segregated rails will fail, and consequently, under such conditions, careful guarding against segregation is as much for the interest of the manufacturer as for

that of the consumer. Fig. 8 represents one such rail which failed under the drop test, and the extent of the segregation is shown by the fact that the proportion of carbon at the outside averaged 0.49 per cent, while at the center of head borings taken with a quarter-inch drill averaged 0.76 per cent.

Also, it will be noted that blowholes extend all along the top of the head.

Such cases as this are, however, rare.

Under " failures due to rough handling " we have found a considerable number from time to time. The initial fracture



FIG. 8. Segregated Rail. Broke under drop test

may, of course, occur either at the mill at straightening presses, or in loading into high side cars and letting fall upon other rails five feet or more below, or in letting the rails fall from the loader six or seven feet upon the ground, and the same thing, of course, may occur after receipt of the rails in unloading unless they are skidded out or otherwise gotten to the ground without any considerable shock. Careful inspection will remedy this condition. A fracture of this type is characteristic. It begins generally across the base of the rail and extends up a short distance into the web, then it works along the web sometimes

for a distance of six feet or more, with the face of the fracture in a plane at right angles to a vertical line down through the rail, and the steel finally snaps off up through the head.

A fracture due to this cause can generally be identified at a glance and can be distinguished from a fracture caused by pipes, since the latter extend with the unwelded faces more or less parallel with the contour of the rail.

To sum up, the results of our investigation indicate that the greater part of the difficulty which occurs to-day with rails under heavy traffic is due to unsound condition of the steel, a condition which existed in comparatively slight degree in the earlier rails.

There has been a marked improvement in practice at some of the mills over that generally prevalent a decade or two ago, and this has resulted at such mills in producing a much finer granular form throughout the section and hence a tougher and better wearing rail if only the metal were sound, but unfortunately, in the essential element of soundness of the steel there has been direct retrogression, making it appear that the main attention in the manufacture has been fixed upon quantity and not quality of the output.

Reading, Pa., June 29, 1905.

A COMPARISON OF STANDARD METHODS FOR TESTING CAST IRON *

By DR. RICHARD MOLDENKE

IN reviewing the situation as it exists to-day, we see that all the work carried through in connection with the testing of cast iron, lies in the direction of standard specifications. The only nations which have accomplished something definite are Germany and the United States. The others are still working at the problem.



As pig iron is the basis of the foundry industry, our attention is first directed to it, and we find two general specifications in use: the American ones, and lately a pig iron contract drawn up in England. In the American specifications we have the direct recommendation that all iron be purchased by analysis. Next, detailed instructions for sampling, — the course to pursue in case of a disagreement in the analytical work. An important omission, and one which it will take much time to supply, is the adoption of standard methods for analysis. Without these, even the best specifications still leave a loop-hole for controversy. Incidentally, it may be said that the American organization of foundrymen is taking this matter up, and has already prepared a standard method for determining silicon in pig iron and cast iron. Total carbon is to follow, then sulphur, and so on. As these methods are tested out in practice outside of the foundrymen's organization, we shall learn their practical value for specification purposes better.

Continuing with the American pig-iron specifications, we next come to the allowances and penalties. Here there is given

* July, 1905, meeting of the American Society for Testing Materials.

the limit of difference allowable in the pig iron delivered from that specified, and the penalty that may be exacted where the limit is exceeded, and yet not be too great to absolutely reject the metal. These provisions enable foundries to purchase pig iron with a reasonable assurance that they get what they want nearly enough, without causing the slightest trouble in the shop routine. The cash penalty further prevents the furnace from taking chances on shipments to people who watch their supplies carefully.

For the benefit of the trade in general, inasmuch as only the minority of foundries are equipped with laboratories, or have expert advice, there is given a table of base analyses of grades, so that if a man pins the specifications to his order, and calls for a No. 3 iron, he will get just what a No. 3 iron should be in composition, so far as the silicon and sulphur is concerned. When the use of chemistry in the foundry is so general, and the furnaces are run in such a way that one iron is as good as another, we may see these specifications extended to include the other elements. At present the phosphorus, manganese and carbons are questions of brand and locality largely, the furnace industry being quite settled in classes for pig-iron distribution.

Germany has not yet seen fit to standardize pig irons, and reports from the other side indicate that conditions are not so favorable there, the application of our American specifications being out of the question for German irons. A man calling for pig iron with the sulphur we give, and be it said that our sulphur limit is high, would have to pay fancy prices in Germany, for they are badly troubled with that element over there. The same may be said for England, and, on looking over the new pig-iron contract issued by the London Metal Exchange, we find that while the sulphur allowed is not much larger than ours, yet the very much higher silicon that goes with it practically makes a big difference. Thus, while we have a No. 2 pig iron run 2.25 silicon, with a variation of 10 per cent either way, or 2.00 to 2.50, and this has a maximum of .045 sulphur allowed, the English standard, with the same sulphur, allows the silicon to vary from 2.50 to 3.50 per cent, which would correspond to our No. 1 with a higher sulphur. The English specifications also give rules for sampling, but lay much stress upon the brand names.

Incidentally it may be mentioned that America is taking up the question of standardizing foundry coke, which is a step in advance, and will have a far-reaching influence, not only in foundry practice but on the blast furnace.

To turn now to specifications for testing cast iron. In America we have adopted a set for pipe, for locomotive cylinders, for malleable castings, and there are pending those for castings in general, and for car wheels. Over here we take out from the general work, the special groups, which can stand by themselves and have properties peculiarly their own, which may be determined by specific tests. In Germany they have specifications for machinery castings, for columns (which we are trying to get away from as quickly as possible) and for pipe.

In dividing the classes of castings relative to their thickness, for this is the important point to consider when specifying breaking strength, we have adopted a little wider limits than the Germans. Thus we have small castings at $\frac{1}{2}$ inch and less. They have 0.6 inches and less, or a little more. For medium castings, however, we have from $\frac{1}{2}$ inch to 2 inches. The Germans have from 0.6 inch to only 1.00 inch. For heavy castings, we have over 2 inches in thickness, and they have over 1.00 inch, which shows that our conception of heavy castings is a little different, or else that German customs lay more stress on smaller limits for medium castings.

A further difference between the American and the German specifications may be found in the chemical end. We specify the upper limit for sulphur, so as to secure reasonable strength against shock. This is not looked after in the German specifications, possibly because of the difficulty in getting low sulphur irons for the foundry.

The point that interests us most, however, is the method by which the metal is judged; that is, the test bars employed. Comparing the general specifications advanced for Germany with our own, now pending, we see that special pains are taken in both cases to get representative test bars, and these are not to be cast on the piece. Herein there is a distinct advance, cutting off the old coupon. The transverse test is prescribed, which agrees with our experience. The tensile test is omitted entirely in Germany, and it is to be hoped that we may follow suit in this some day also, as no good end is served when no

two testing machines may agree in the alignment and grip on the specimens.

We find a radical difference in the length of the test bars used. Our own are comparatively short, and this has caused comment on the other side, our German brethren concluding that we do not lay as much stress on the transverse test as we should. We, on the other hand, believe that with the long bars in use formerly, much of the sensitiveness of the transverse test is gone, for even poor iron will show good results, if the test is carried out slowly and carefully. On the other hand, with a comparatively quick test on short bars, the iron must be of good quality to show a good deflection and strength.

Three bars are provided by the Germans: for small castings the diameter is 0.8 inch and the distance between supports 16 inches. For the medium castings the figures are 1.2 inches diameter and 24 inches between supports. For the heavy castings the diameter is 1.6 inches and the testing distance 32 inches.

It will be noted that the German aim is evidently to get as near the size of the castings to be represented as possible, and this is to be commended in a way. However, we realize over here that the lack of homogeneity in the structure of cast iron is such an element in the problem that the records of several sized test bars are not mathematically comparable, as would be the case in steel. Hence we would not feel safe to accept the result of a long and thick bar as compared with a shorter and thinner one, in order to judge whether the iron in one is better than that in the other.

While realizing that it is desirable to vary the diameter of the bars, but not the length, we reluctantly confined ourselves to one bar for all purposes, aiming only to get at the actual quality of the metal with given standard conditions, identical for each test, so far as foundry practice can accomplish this. We can, therefore, discriminate between metal wanted for light, medium and heavy castings at a glance, and without making a comparative calculation, the results of which are open to doubt.

The German specifications for casting the test bars go us one better in requiring the vertical pour, but from bottom up. We await their results on this with interest, as we use the ordinary top pour, but so arranged that the metal drops to the bot-

tom through a funnel-shaped gate, and the mold is thus made cheaper.

German specifications call for the bars to be made in flasks that are not parted, if possible, so that the test bar has seams. If, however, this is unavoidable, the test bar is to be so placed that when tested the seam lies in the neutral axis. We prefer to prevent test bars made with seams altogether by giving complete specifications for the flask itself, which any foundry can arrange for without particular trouble.

Both specifications agree in having the bars cast in dry sand, and the cooling of the bars in the flask. Furthermore, only brushing is allowed in cleaning the bars, and no machining is to be done.

In judging the tests themselves there is a difference between the two specifications in question. We specify just when the tests are to be arranged for in the heat, and that one of the two bars cast at the various casting intervals must pass the requirements. The German specifications call for three bars, the average of which must be taken, defective bars to be excluded. In both cases the expense of testing falls upon the founder. In our added tensile test, this, when required by the purchaser, is to be paid for by him.

The clause in our specifications wherein we allow the buyer the freest run of our establishments, in order that he may be satisfied that the material is gotten out in the best manner possible, does not appear in the German specifications. Only in the case of pipe is there mention made of facilities to be given the inspector to watch the testing of this material.

It is still a little early to draw conclusions from the specifications advanced, for they have either not been officially adopted by their respective countries, or they are still in the trial stage. This much can be said, however, that a marked advance can be recorded, for in everything presented so far, the attempt has been made to build on our increasing knowledge of the properties of cast iron as a metal. Much has, of course, to be yielded to business expediency, for the industrial customs of a nation cannot be radically disturbed without laying ourselves open to the charge of being idealists and dreamers.

The buying of pig iron by analysis, and now by specification, may be said to be the most radical advance the foundry

has ever made. The adoption of specification for castings is gradually coming into vogue also, and we will soon see the allied industries, such as the fuel, sand, facings, etc., become a subject for study and final specification.

It is to be hoped that at Brussels, next year, we not only may report final specifications for all we have undertaken in the way of cast iron, but that Germany, England, France and Austria may be similarly situated. Then we can compare notes, and possibly adjust some of the items so as to have a greater conformity in practice.

RECENT DEVELOPMENTS OF THE BERTRAND-THIEL PROCESS IN THE MANUFACTURE OF STEEL *

By JOHN H. DARBY, Brymbo, and GEORGE HATTON, Round Oak

MANY attempts have been made to accelerate the open-hearth process of steel making, acid or basic, by increasing the size of the furnaces employed, perfecting the machinery for charging the steel-making materials, using molten iron from the blast furnaces, regulating its supply and composition by the use of a mixer, etc., and the object in view has more or less been accomplished. But with all such improvements, in practice it is generally found essential to employ pig metal of special composition, which is not always readily obtained, and may be somewhat costly to manufacture.

The authors hope to show that by the aid of the Bertrand-Thiel process a variety of pig irons may be used, differing in composition, while at the same time the output of steel is kept at its maximum, and the quality of the product uniformly excellent. A. Ledebur † observes "that if two substances react on each other chemically, this reaction proceeds more slowly the more the two substances are diluted by other substances which remain inert. In other words, the greater the excess of one of the two reacting substances the more quickly is the chemical conversion of the other completed." This, in the authors' opinion, is the basis for the use of two furnaces in the Bertrand-Thiel process.

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* Iron and Steel Institute, May, 1905, meeting. Slightly abridged.

† "Stahl und Eisen," Vol. XXIII, pp. 36–41.

When in 1894 Messrs. Bertrand and Thiel introduced their process at Kladno, it was the practice, as open-hearth furnaces existed at a suitable level, to hold the molten iron in these furnaces ready for the basic converters, and to effect a certain amount of refining, by additions of ore and lime, in order to prepare the metal for blowing. A 20-ton open-hearth furnace also existed at a lower level, sufficiently near to be commanded by a long trough connecting the upper and lower furnaces. With these conditions, it occurred to Bertrand and Thiel that preliminary refining, or roughing down, might with advantage take place in the upper or primary furnace, and that when the bulk of the phosphorus, and incidentally the whole of the silicon with part of the manganese and carbon, had been removed, they would have metal highly suitable as regards composition and temperature for transfer to a secondary furnace, in which suitable proportions of scrap, iron ore and lime had been previously charged and heated, care being taken to prevent the slag from the primary furnace passing to the secondary furnace during the transfer of the metal.

Prof. H. M. Howe has aptly described the process as analogous to washing one's hands in water, so making them moderately clean, and subsequently changing to fresh water, where the final degree of cleansing can be attained.

As by the medium of the first washing a moderate degree of cleansing is attained, so the feebly basic slag in the primary furnace is able to retain a large percentage of the phosphoric acid and silicon liberated by the oxide of iron. Slags from the primary furnace frequently hold double the percentage of phosphoric acid compared with the lime base.

The following is a typical analysis of primary slag when using phosphoric pig iron:

SiO_2	10.22%
P_2O_5	28.86
CaO	18.60
Fe_2O_3	6.70

Notice how feebly basic the slag is, and yet how perfectly the iron in the ore has been exhausted, while the slag is largely charged with phosphoric acid. A yield of 103 to 105 of steel ingots per 100 of metal is attained.

This means saving in lime consumed to fix the phosphorus removed from the pig treated, and insures a high percentage of the phosphoric acid in the slag, usually over 90 per cent of which is soluble according to the standard test.

As Bertrand worked his process, six to seven 20-ton charges of soft steel per twenty-four hours were considered good practice for a pair of furnaces. At Brymbo, with a more highly phosphoric pig, seven similar charges per day during a week's working have been attained. At the Hoesch works in Dortmund ten charges have been regularly produced per day.

Fast working means a reduction in the cost of conversion, so that at present, taking into consideration the outlay involved, the Bertrand process may claim to be operated as economically as any other known method of converting pig metal into steel.

Bertrand's original plant, with furnaces at different levels, can only be used under special conditions, and had the disadvantage that when one furnace was under repairs the other had to remain idle.

Many works have their furnaces arranged in line, and to suit this construction a convenient arrangement is to place a mixer at one end or in the center of a line of furnaces, commanding the whole by powerful overhead cranes and charging machines to charge the metal from the mixer to the primary furnace, and, after partial purification, to transfer again to the secondary furnace for final treatment.

An arrangement of plant well suited for the process is shown on Figs. 1, 2 and 3 herewith.

Any scrap that it is desirable to melt up and make use of is charged into the secondary furnace, and the quantity so used is only limited by the time occupied in charging the furnace and melting. A pair of furnaces, working 16 tons of phosphoric pig in the primary, and 20 tons with scrap in the secondary furnace, would tap at least every two and one-half hours, so that charging by pouring in molten metal and mechanical charging of the scrap are desirable, and even necessary, to obtain the best results.

A mixer is no part of the Bertrand-Thiel process any more than it is of the Bessemer or Thomas processes.

In the case of two works employing the Bertrand-Thiel process, the pig iron containing a high percentage of phosphorus,

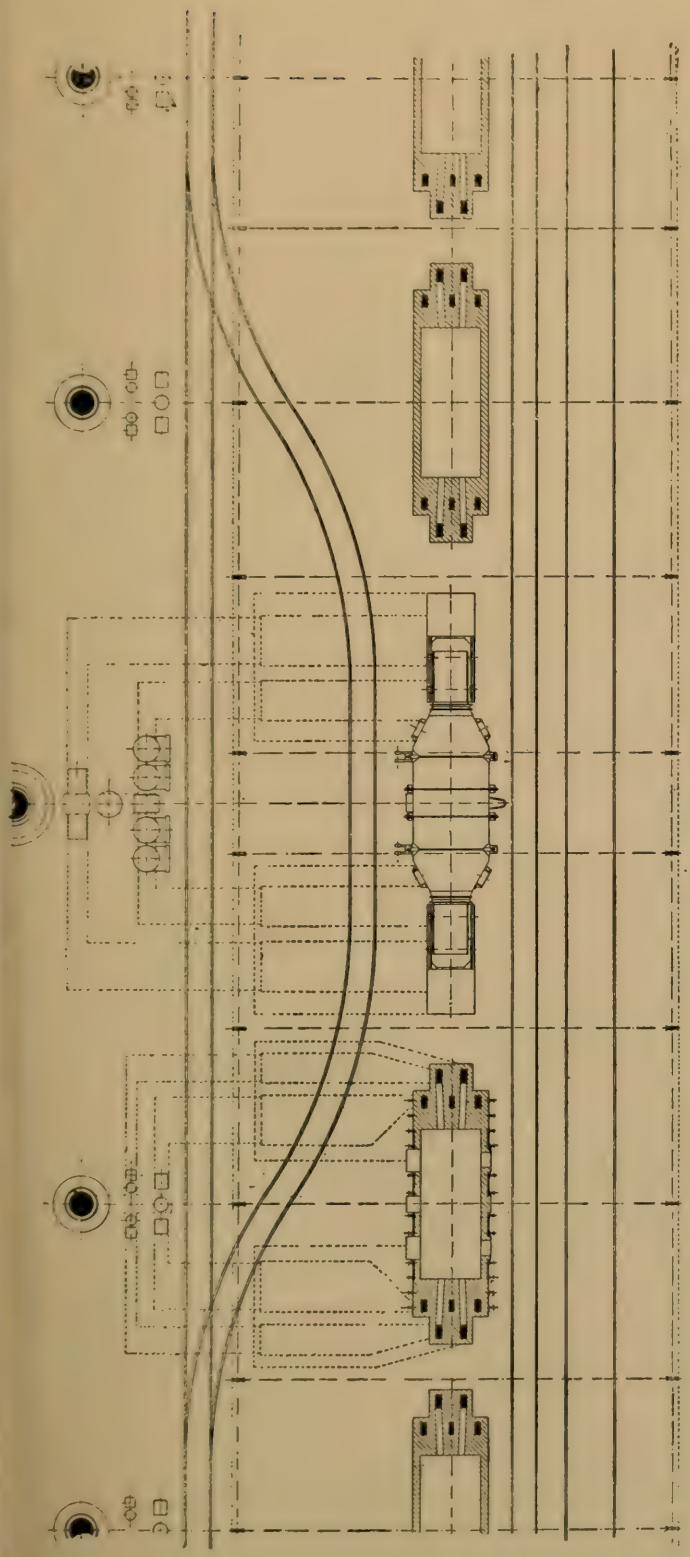


FIG. 1.—General Plan.

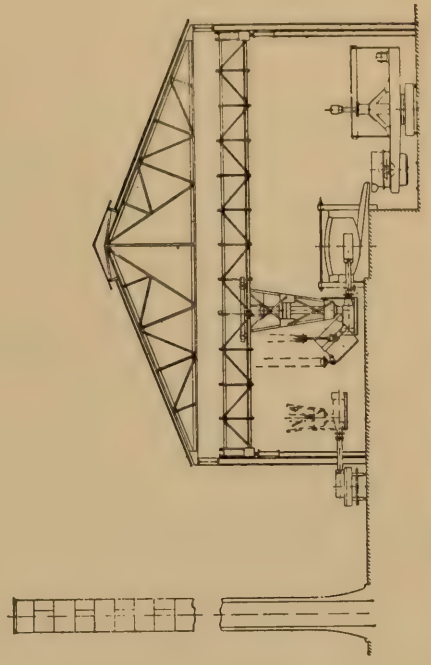


FIG. 3.—Elevation through Open-Hearth Furnace, showing Charger and Locomotive Casting Crane.

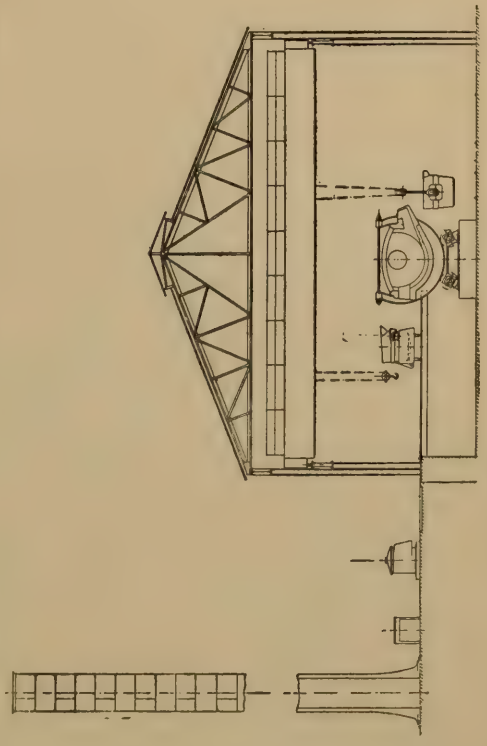


FIG. 2.—Elevation through Tender, showing Crane.

it was found advisable to employ a gas-heated mixer, in fact, a large tipping gas-heated furnace. In it the molten metal from the blast furnace is poured and retained for use as required, week-end metal melted, desulphurization takes place, and the percentage of silicon is reduced. If a temperature of about 1500° C. is maintained in the furnace, cold pig iron is readily melted, and the wear and tear of the furnace is slight.

	Average Composition of Metal charged to Mixer	Average Composition of Mixer Metal ready for Steel Furnaces	Average Composition of Primary Metal	Average Composition of Final Metal
	Per Cent	Per Cent	Per Cent	Per Cent
Carbon	3.250	. . .	1.800	0.11
Silicon	0.654	0.473	0.080	0.46
Sulphur	0.076	0 040	0.036	0.028
Phosphorus	2.420	. . .	0.580	0.035
Manganese	2.400	0.510	. . .	. . .

Note the reduction in sulphur and silicon in the mixer, and that the carbon remains almost untouched.

The mixer is a costly piece of apparatus, and in order to get a better return in work done than is described above, it was decided, as an alternative to working the process as originally employed by Bertrand, to carry the refining in the mixer still further, only raising the temperature sufficiently high to melt the slag while adding a considerable quantity of iron ore and lime.

	Average Composition of Pig Metal charged into Mixer as Primary Furnace	Average Composition of Refined Metal from Mixer as Primary Furnace ready for Secondary Furnaces	Average Composition of Final Steel from Secondary Furnace
	Per Cent	Per Cent	Per Cent
Carbon	3.25	2.10	0.169
Silicon	0.636	0.160	0.042
Sulphur	0.053	0.043	0.028
Phosphorus	2.42	0.930	0.032
Manganese	2.40	0.78	. . .

The average temperature of the furnace, looking on to the surface of slag through the central door, was 1545° C. as shown

by the Wanner pyrometer, compared with the secondary furnace in full heat of 1720° C.

It will be noticed that the carbon largely remained, the silicon was almost all eliminated, the sulphur reduced and 61.5 per cent of phosphorus removed. Counting the mixer as a primary furnace, three furnaces were engaged, the two secondary furnaces charged with 25 per cent scrap working up the output of the mixer with forty-two 20-ton charges between three furnaces, or fourteen charges per week per furnace.

The added ore in the mixer was well exhausted. The speed of working was slower than the first modification of the process tried.

Average composition of mixer slag:

Silica	15.5%
Ferric oxide	9.0
Phosphoric acid	18.5
Lime	19.5

The original method of working employed by Bertrand has the advantage of faster working. The second method, although not so expeditious, involves less trouble in transfer, but is trying to the lining of an important furnace like the mixer.

In both the methods described phosphoric iron was employed, made with specially low percentages of silicon and sulphur.

As it had been noticed that sulphur was very readily eliminated in the primary furnace, irons were obtained containing high percentages of sulphur and silicon in order to test the process.

The following are notable instances:

Percentage of Sulphur in Pig Metal	Percentage of Sulphur in Primary Metal	Duration of 18-Ton Charge in Primary Furnace		Percentage of Carbon in Primary Metal
Per Cent	Per Cent	Hours	Mins.	Per Cent
0.308	0.060	2	45	2.2
0.209	0.070	2	15	1.6
0.240	0.078	2	40	1.8
0.370	0.100	3	...	0.9

The percentage of sulphur in the finished steel from the secondary furnace did not in any case exceed 0.05 per cent.

Pigs with 2 per cent to 2.5 per cent of silicon are readily treated in the primary furnace, and owing to the short duration of the charge no excessive wear of the lining takes place.

From experience gained the authors can state that by partial preliminary refining in one furnace, pig of almost any ordinary composition can be commercially treated.

THE CONTINUOUS STEEL PROCESS IN FIXED FURNACES*

By S. SURZYCKI, Czenstochowa, Poland

THE process is based on the idea and the principle of the Talbot process, with the essential difference that it can be carried out in any fixed furnace of not less than twenty-five tons capacity. This practice is mainly based on the arrangement of two or more tapping holes placed over each other, but not arranged in a vertical line, such tapping holes leading into a double launder by which the whole of the contents of the furnace, or only a part of the contents, may be easily emptied at any time. The tapping holes are arranged in a cast-iron plate, lined up with magnesite bricks and stamped dolomite; they give no trouble since they can neither slip nor sink, nor yet be corroded. The closing of the tap holes is carried out as follows: When the molten bath has so far sunk that it is on a level with the bottom of the tap hole, it is agitated by means of a rabble, by which means the bottom of the tap hole is perfectly freed from metal. Immediately thereupon some shovelfuls of dry burned dolomite are thrown against the tap hole from the charging side of the furnace, and the last drainings of metal are removed from the tapping side, and it is then made fast on that side. The whole operation lasts some few minutes.

The hearth of the furnace stands perfectly, and remains sound for months without any repairs. As a rule only the slag line, and to a less extent the blocks, require repair.

At the Czenstochowa works there is at work a 25-ton furnace of the following dimensions: The length between blocks, 26 feet, 3 inches; width, 8 feet, 7 inches; and depth of hearth from 1 foot, 8 inches, to 2 feet. During its first campaign it made

* Iron and Steel Institute, May, 1905, meeting. Slightly abridged.

574 charges by the continuous process, whereupon, while still in quite good condition, it was stopped for certain local reasons. After repairing the ports and the roof and repacking the chambers, the furnace was again put into work, and since then has already made over 690 charges, and will, it is hoped, keep at work up to the 1,000 charges.

The chief material required for the continuous process is, of course, pig iron, employed in a molten condition. On this point the conditions under which the furnace has to work have not been specially favorable. The pig iron taken from a 70-ton mixer, into which it is run from a single blast furnace, could be improved both as to homogeneity and quality. This molten pig iron is also taken from the same blast furnace for other small furnaces at the same time. The variations in the chemical composition of the pig iron are very considerable, as the following shows:

Carbon	up	to 3	%
Graphite	up	to 3.7	
Silicon	0.8	to 1.9	
Manganese	0.6	to 1.5	
Phosphorus	0.5	to 0.8	
Sulphur	0.02	to 0.10	

These variations have a great influence on the production of the furnace, and in order to lessen them as much as possible the hotter and more graphitic pig iron is treated with iron ore (Krivoi-Rog ore with about 63 per cent of iron). This is a well-known method in the foundry, and consists simply in throwing with shovels the fine previously heated and dried ore into the stream as it runs into the movable ladle.* There is produced thereby a more or less intense reaction, according to the temperature and according to the composition of the pig iron, which promotes the conversion of graphite into combined carbon, and the oxidation of the silicon and manganese.

The pig iron, somewhat refined by this treatment with ore, when brought into the furnace requires less ore there, and works down quicker. The production of the furnace is very closely dependent on the quality of the molten pig iron. It is clear that the graphitic pig iron rich in silicon will take much

* Mr. R. M. Daelen formerly constructed an apparatus for this purpose.

longer to work down than one without graphite and with a less percentage of silicon; especially is the influence of large variations in the chemical composition of the pig iron of importance, as the ore and lime additions have to be measured by the eye.

This composition plays a rôle in this process only in reference to the graphite and sulphur. As before stated, pig iron rich in graphite is difficult to treat in the open-hearth furnaces, the percentage of manganese is not essential, and is only so far of importance that a higher percentage of manganese retards the refining process. The percentage of phosphorus can go very high; with more than 1 per cent of phosphorus the slag must be drawn off as quickly as possible after the reaction, that is, after the end of the refining period, since it is known that the reduction of the phosphorus from the slag can take place, which must be avoided; a very rich phosphoric slag, which can be sold for agricultural purposes, can be obtained.

The furnace makes usually three charges in the twenty four hours, each of 25 tons; when the blast furnace is working well, and a pig iron with low silicon and manganese is obtainable, four charges can be made. The following record of the work of the furnace for a recent month illustrates the results obtained by this process:

CONSUMED

	Tons	Kilos per 1 Ton of Good Ingots
Cold pig iron	140.80	70.3
Molten pig iron	1,809.50	903.1
Ferro-manganese	20.9	10.4
Scrap	19.8	9.9
Iron ore (Krivoi-Rog)	458.1	228.6
Lime	144.3	72.0
Aluminum	0.08	. . .
Burned dolomite	107.7	53.8
Chrome ore	2.0	1.0

PRODUCED

Good ingots	2,003.7 tons
Scrap	41.8 tons
Working days	26
Production per day	77.07 tons
Yield	102.72%

From the above figures it is seen that the yield (reckoned on the metal charged) is 102.7 per cent; but it must be stated that the daily reports are made up with a certain amount of circumspection, and it may be taken that the average yield is not less than 103½ to 105 per cent. From this one could easily reckon the reduction of the iron from the ore. In the Krivoi-Rog ore there is an average of 63 per cent of iron; that is to say, in the whole amount of ore introduced there are 288.6 tons of iron. Since in the pig iron added there is 5 per cent of foreign bodies, and for the other metals added 5 per cent of loss can be taken, there has been, if we take the average yield at 104 per cent, 180 tons of iron or 62.3 per cent reduced. This reduction of iron from the ore in an essentially oxidizing apparatus, such as the open-hearth furnace, must be looked upon as a great advantage, and it is scarcely possible in any other refining operation, even in the Talbot furnace, to obtain a greater reduction.

Unfortunately, I am not able to give exact figures as to coal consumption, since the producer plant is common to the whole of the furnaces, and it will only be when the new continuous furnace, now building, which will have separate producers, is working that it will be possible to give the coal consumption exactly. Of course, it is considerably less than the ordinary process, as the furnace when continuously worked stores up an immense amount of heat, and much less fresh gas than in the ordinarily worked furnaces is required. It can, however, be stated that the coal consumption for the whole steel plant (which consists of five furnaces, four of which are ordinarily in operation), since the introduction of the continuous process, has fallen about 9 or 10 per cent (reckoned on the production of good ingots).

A few words on the quality of the material produced may be useful, as this subject does not appear to have been very clearly understood.

The making ready of the charge, according to the method described above, and also according to the Talbot process in tipping furnaces, takes place partly in the steel ladle. I say advisedly "partly," as actually the charge must be finished sufficiently in the furnace itself. The test taken from the furnace before tapping, and before the addition of ferro-manganese, must be capable of being hammered out without any fault,

must possess the wished-for hardness, must be perfectly dephosphorized, must show a perfectly sound fracture, and must remain quiet in the small test ingot mold. This being so, the charge can then be tapped, and at the same moment a regulated amount of finely ground ferro-manganese is thrown against the stream of steel as it falls into the ladle. A fairly active reaction is thereby produced, which after one to one and a half minutes quiets down completely, and when the metal has stood for a short time teeming can be commenced. In order to treat the charge rightly by this method undoubtedly a certain amount of experience must be had; but it appears incomprehensible why by this method just as good a quality of steel should not be obtained, as some steel works managers have asserted. In the first place, the quality of the final product is dependent on the quality of the pig iron employed. It is clear that from a pig iron rich in sulphur or copper it is more difficult to produce a good quality than from a good first-class pig iron. In this connection one can always help matters by the addition of spiegel or in other ways even more easily in the continuous process, as the impurities in the pig iron are taken out more easily and with less trouble by admixing it with the soft, pure bath of metal remaining in the furnace than in the ordinary process, where one would have to treat the bad pig iron alone. It must be observed that in the 25-ton furnace with the deeper hearth, 25 tons, as a rule, are tapped, and the same quantity of molten pig iron poured in, 15 tons of pure soft metal being left behind. Thus the capacity of the furnace by this process is increased to 40 or 45 tons, although it was constructed as a 25-ton furnace only. In the second place the dephosphorization by means of the slag goes on quicker in the continuous process, since the pig iron while being poured into the furnace is already partly dephosphorized during the reaction which takes place. Further, the charge must be very carefully worked down before tapping and before the addition of the ferro-manganese, since the influence of the calculated amount of ferro-manganese, which is added in the ladle, is only to bring about the deoxidation of the metal and the introduction of the necessary amount of manganese into the steel. Finally, an imperfect admixture and an imperfect influence of the ferro-manganese is, as a rule, impossible, as the lively reaction which is produced proves.

It is obvious that special quality steel is more easily made ready in the furnace itself than in the ladle, but the above method gives results leaving nothing to be wished for when producing a first-class quality of soft ingot iron.

The ingot iron produced by the continuous process leaves nothing to be desired. The same may be said as to the homogeneity of the material. As is well known, open-hearth ingot iron is never absolutely homogeneous, so that one does not speak of ideal homogeneity, but the metal made ready in the ladle itself is quite as homogeneous as that made by the ordinary process with the additions added in the furnace.

However, in order to be in a position to decide finally as to the homogeneity of the product, a parallel series of carefully conducted analytical experiments were carried out on ingots made by the continuous and by the ordinary processes. The experiments were made as follows: On the same day two charges were taken, one from furnace which was made ready in the furnace itself in the ordinary way, and the second from the continuous furnace, which was deoxidized in the ladle by the addition of ferro-manganese. These were analyzed and the results showed that the differences in the composition are very nearly the same; in the continuous process the differences as regards the carbon and manganese are rather less, and as regards the phosphorus rather greater. In both cases the metal was very hot, and thus the variations in the composition are not inconsiderable. This latter circumstance, however, is in the present instance not so important as the composition itself; let the variations be more or less great, they are due, as is well known, to variations in temperature and to other conditions. But these experiments have a great importance, as they demonstrate that metal made (*a*) by the ordinary process and (*b*) by the continuous process are similar to each other and make it clear that the former fears as to the metal deoxidized in the ladle being less homogeneous than that produced by the ordinary process were perfectly groundless.

The continuous process can naturally be still further developed, but in any case it has shown, during the last two years of practical work, its capabilities and advantages. These advantages do not consist solely in the continuity of the process itself, but in the longer life of the furnace, the higher production

and yield, the lessened fuel consumption, and also in the simplicity of the whole plant and of the whole practice. There may be here and there some imperfections in connection with it, as is the case with everything new, but these will, it is to be hoped, be overcome with time.

COPPER ALLOYS *

SPECIAL BRASSES AND QUENCHING OF BRONZE

By L. GUILLET

Translated from the French for The Iron and Steel Magazine

(*Concluded from page 29, Vol. X*)

Aluminum Brass — Theoretical Study. The characteristic part played by aluminum in metallurgy is that of a deoxidizing agent. Although no exhaustive study has yet been made of aluminum brass, it has been known for several years that an addition of 2 or 3 per cent of aluminum to a brass of the type Cu, 70 per cent, and Zinc, 30 per cent, gives a product having nearly the structure of forgeable bronzes and also a similar strength.† In our experiments we started with two types of brasses containing respectively 70 and 60 per cent of copper, and to these were added from 1 to 10 per cent of aluminum, replacing in every case equal proportions of zinc. Aluminum was added in the metallic form, most of it in the crucible before melting and the balance immediately before casting. It was found that with .5 to 1 per cent of aluminum and 60 per cent copper the alloy assumed a beautiful gold color and that this color was retained up to 5 per cent of aluminum, when it became pinkish. With 7 per cent of aluminum a superb rose color is produced, appearing gray under a certain incidence of light. With 10 per cent of aluminum the alloy is white. Up to 4 per cent of aluminum the metal can be worked hot, but with a larger proportion of that element working becomes very difficult, the metal breaking if drawing be attempted.

The structure of these alloys is shown in Figs. 24 to 31. An addition of .5 per cent aluminum to a brass containing 60 per

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* "Revue de Métallurgie," February, 1905.

† Charpy, "Researches on Alloys of Copper and Zinc."

cent copper does not produce any structural change. With 1 per cent aluminum the crystals of ZnCu are much more widely separated. With 2 per cent of aluminum the crystals character-

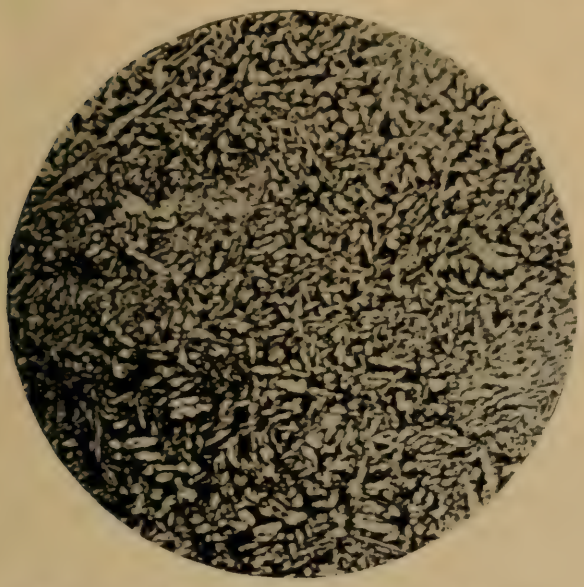


FIG. 24. Cu, 60%; Zn, 39.5%; Al, .5%. Magnified 50 diam.



FIG. 25. Cu, 60%; Zn, 36%; Al, 4%. Magnified 50 diam.

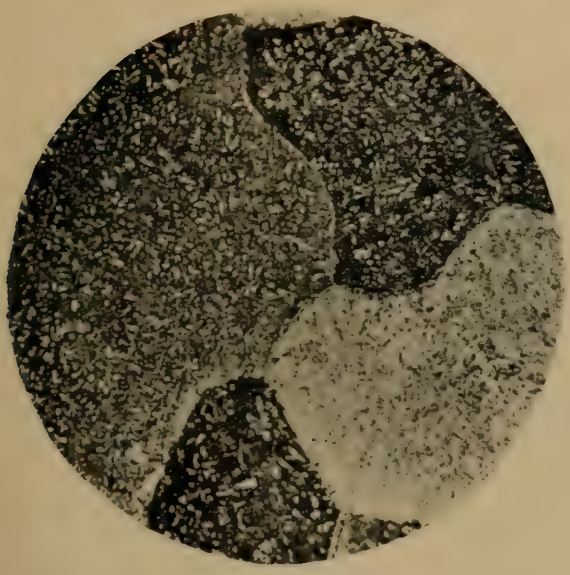


FIG. 26. Cu, 60%; Zn, 34%, Al, 6%. Magnified 50 diam.

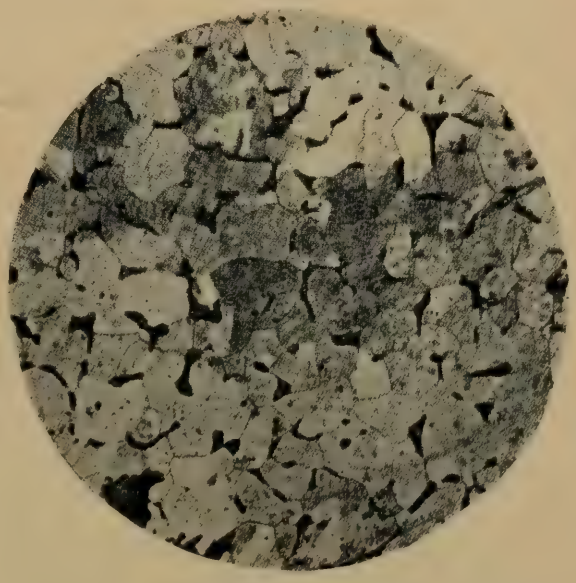


FIG. 27. Cu, 60%; Zn, 33%; Al, 7%. Magnified 50 diam.

istic of forgeable brasses are no longer found, being replaced by polyhedric grains similar to those present in brass containing less than 55 per cent copper. With 5 per cent aluminum poly-

hedric grains are found containing small crystals similar to those discovered by Charpy in brass with about 50 per cent copper. With 7 per cent aluminum the grains are surrounded by a number

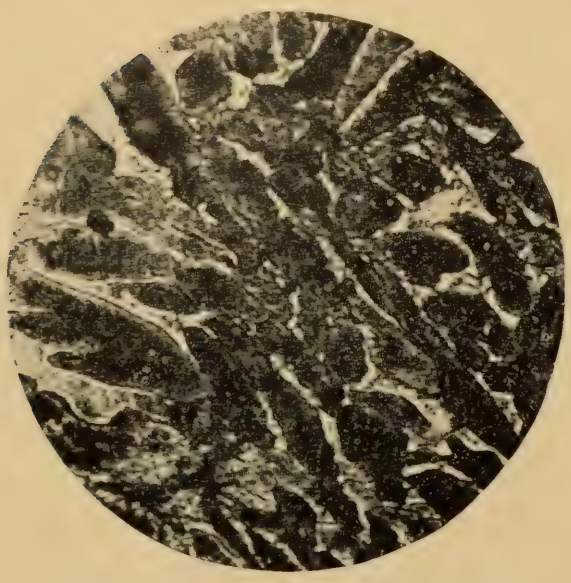


FIG. 28. Cu, 70%; Zn, 27%; Al, 3%. Magnified 200 diam.



FIG. 29. Cu, 70%; Zn, 25%; Al, 5%. Magnified 200 diam.

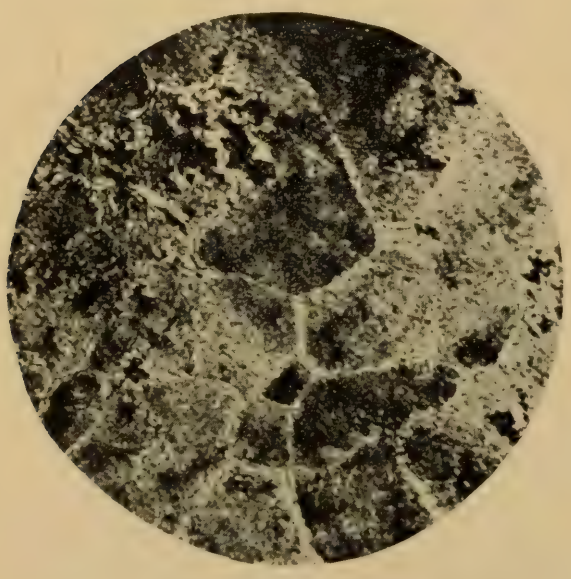


FIG. 30. Cu, 70%; Zn, 22%; Al, 8%. Magnified 200 diam.



FIG. 31. Cu, 70%; Zn, 20%; Al, 10%. Magnified 200 diam.

of dark areas. The alloy containing 10 per cent aluminum was so brittle that it was not possible to polish it. Passing to the brasses containing 70 per cent copper, when the proportion

of aluminum does not exceed 3 per cent the structure remains that of ordinary brass. Upon exceeding that amount, large crystals of forgeable brass appear in the structure. With 6 per cent of aluminum polyhedric grains only are found, while with 10 per cent of aluminum, the grains are found to contain numerous small crystals.

To sum up, aluminum brasses have a structure similar to those alloys containing a larger percentage of zinc. Their color and behavior when worked lead to the same conclusions. For instance, with 60 per cent copper, 2 per cent aluminum and 38 per cent of zinc, the structure is similar to that of a brass containing 55 per cent copper and 45 per cent zinc. An addition of 2 per cent of aluminum appears to have the same effect as 7 per cent of zinc, 1 per cent of aluminum being equivalent to 3.5 per cent of zinc. Further comparison justifies this conclusion. It will be seen in the following pages that the same holds true with regard to the mechanical properties conferred respectively by 1 per cent of aluminum and by 3.5 per cent of zinc.

Manufacture. — Aluminum brass is obtained by melting together copper, zinc, and aluminum. As the latter metal is difficult to alloy, because of its low specific gravity, the molten mass should be mixed with care. A small amount of aluminum, moreover, should be reserved for addition just before casting, when it will act as a purifier. Instead of metallic aluminum a copper alluminum alloy, prepared for that purpose, is frequently used. The aluminum brasses generally used are of the following two types:

Cu 68 to 70%, Zn 31 to 27%, Al 1 to 3%.
Cu 59 to 61%, Zn 40.5 to 47.5%, Al .5 to 1.5%.

Properties. — Aluminum brasses have a very close grain and possess a tenacity greatly superior to that of ordinary brass. The results obtained in our experiments are shown in diagrams 8, 9 and 10. From these results the following inferences may be drawn: (1) Aluminum increases slowly the tenacity and the elastic limit; (2) at first it increases the elongation and then decreases it; (3) when present in small amounts it increases decidedly the shock resisting quality of the alloy; (4) it increases the hardness only when present in relatively large quantity, but the alloy becomes then very hard.

Uses. — Aluminum brasses are employed for the same purposes as manganese brasses. It might be added that in France aluminum brass has been used in the construction of submarine boats, but it did not give entire satisfaction.

Other Special Brasses — Complex Types. To make these experiments exhaustive the influence of some other elements should have been studied, especially that of iron, vanadium, nickel, cobalt, silicon, etc. These researches have been undertaken and the results will be published in a few months. It may be stated now that the high tenacity brasses which are wrongly sold as bronzes are very complex. They are made up

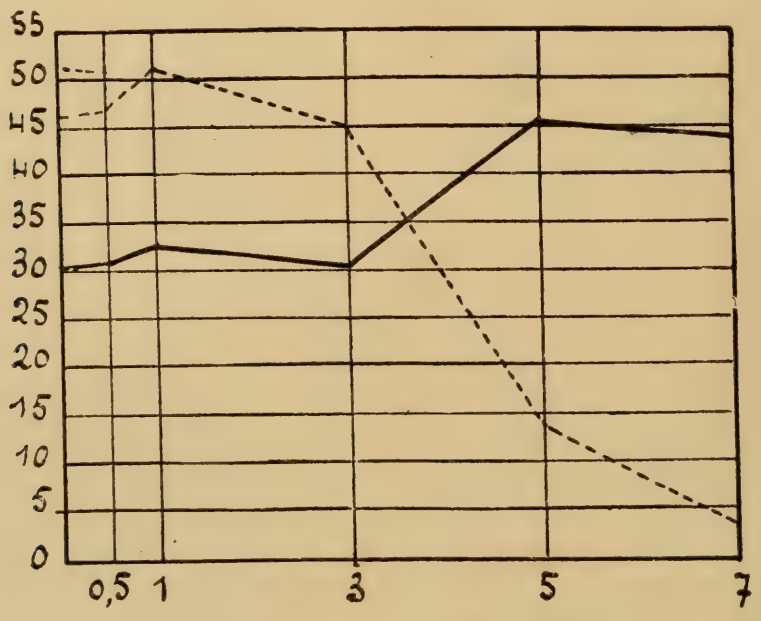


DIAGRAM 8. Aluminum Brass. First type

of four, five and even of a greater number of constituents. They may, however, be classified in two groups: (1) Those containing from .5 to 1 per cent of manganese and a little tin, iron and aluminum, and (2) those containing 2 per cent of manganese and a little tin, iron and aluminum.

Quenching of Bronzes. — In some very important experiments Messrs. Heycock and Neville have shown, apparently in a conclusive manner, what was the constitution of copper tin alloys, that is, of ordinary bronzes. According to these investigations at the ordinary temperature, bronzes containing over 75 per cent of copper may be divided into two classes: (1) with 0 to 9 per cent of tin they form a solid solution α, and

(2) with 9 to 31 per cent of tin a solution *a* and a definite compound *δ* answering to the formula Cu_4Sn. The bronzes contain-

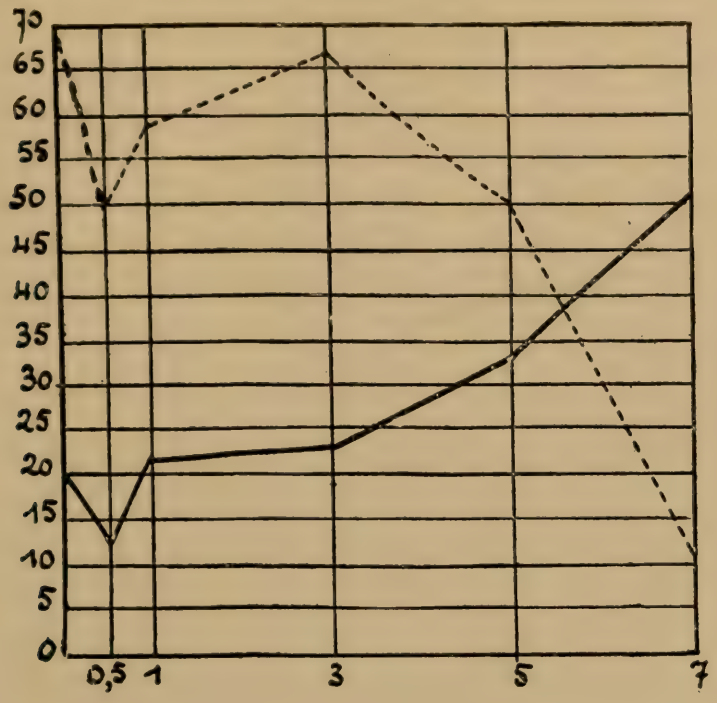


DIAGRAM 9. Aluminum Brass. Second type

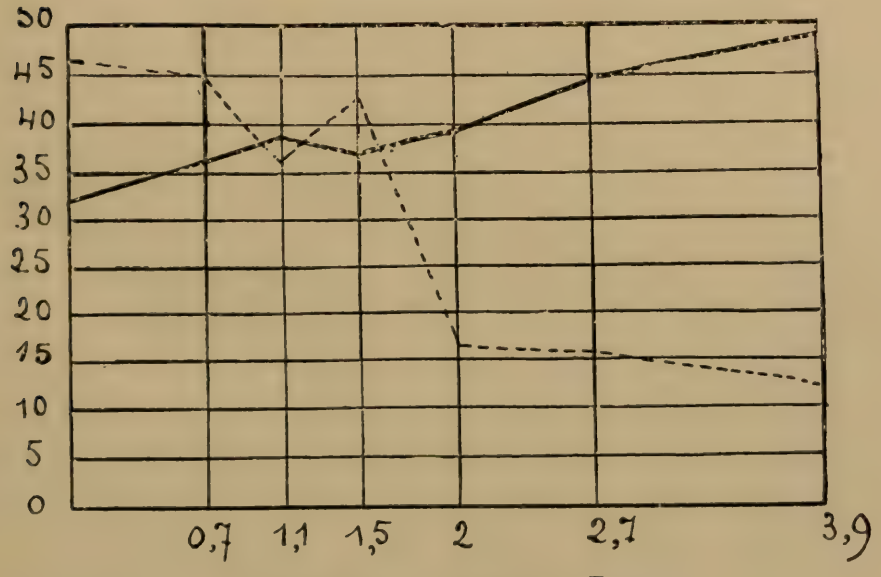


DIAGRAM 10. Aluminum Brass

ing less than 9 per cent tin are always composed of the solution *a* whatever their temperature, while with 9 to 22 per cent of tin the bronzes change their constitution at 500° C., being then

composed of the solution δ and of a solution β, the latter containing from 22.5 to 27 per cent of tin. With a larger proportion of tin, the change of constitution is more pronounced. It occurred to us that these transformations might have an industrial interest, and we were led to study the quenching of these alloys by which the metal could be maintained in the conditions existing at higher temperatures. It should be borne in mind in this connection that even now bronzes are occasionally quenched. Mr. Rich, moreover, has shown that some bronzes containing as much as 10 per cent tin could be rolled when heated to a cherry red color while they could not be rolled in the cold. In our experiments samples of bronzes containing from 0 to 22 per cent of tin were quenched at temperatures increasing between 300° and 800° C. The results obtained are tabulated below:

TYPE I. Cu = 79 Sn = 21

Quenching Temperature	Tensile Strength, Kilos per sq. mm.	Elongation %	Reduction %
Not quenched	20.0	5.5	0
550	38.6	12.2	2.8
650	38.3	11.1	0.7
700	35.8	21.2	2.9
750	35.2	23.2	1.5

TYPE II. Cu = 84 Sn = 16

Quenching Temperature	Tensile Strength, Kilos per sq. mm.	Elongation %	Reduction %
Not quenched	25	4.7	1.4
300	22	?	0
400	24.4	?	0
500	19.4	5.6	1.4
550	40.1	10.1	5.9
600	42.6	?	3.6
650	36.3	?	1.4
700	34.4		2.9
750	29.6	?	5

TYPE III. Cu = 87 Sn = 13

Quenching Temperature	Tensile Strength, Kilos per sq. mm.	Elongation %	Reduction %
Not quenched	24.1	13.7	3
500	21.7	14.0	3
550	23.7	?	5
600	28.0	10.5	10
650	28.0	8.4	9
700	28.0	10.4	13
750	30.5	?	19
800	25.4	8.4	9

TYPE IV. Cu = 91 Sn = 9

Quenching Temperature	Tensile Strength, Kilos per sq. mm.	Elongation %	Reduction %
Not quenched	25.4	10.3	16.5
400	18.4	10.5	14
500	18.4	10.5	11.5
600	25	9.2	23.5
700	25	10.5	23.5
800	20.7	7.1	30
900	3.9	3.9	2

TYPE V. Cu = 95 Sn = 5

Quenching Temperature	Tensile Strength, Kilos per sq. mm.	Elongation %	Reduction %
Not quenched	19.2	?	20
300	24.0	10.3	27.5
450	24.6	11.1	27
550	23.4	6.8	28
600	21.0	?	27
650	19.3	6.1	25
700	19.3	4.8	20
750	19.2	7.5	22
800	6.7	?	3

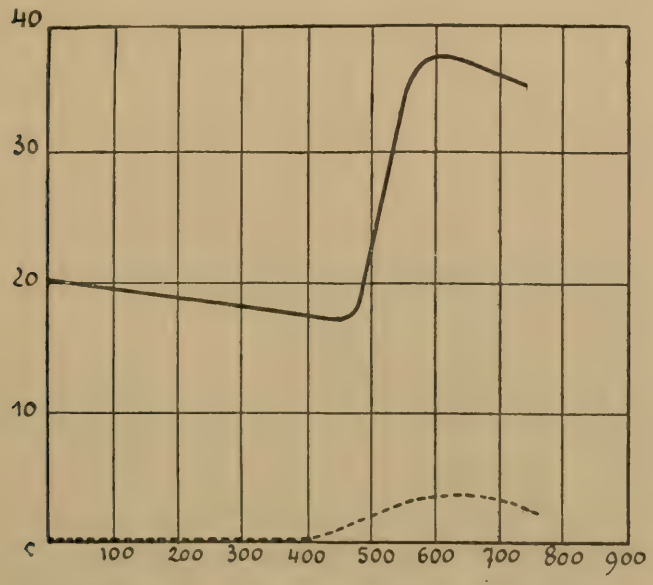


DIAGRAM 11. Type 1. Cu, 79%; Sn, 21%

If these results are compared with those shown in diagrams 11 to 15, the following conclusions may be drawn:

1. In the case of alloys containing over 92 per cent copper, the tenacity is slightly increased by quenching between 400° and 600°, and the elongation is similarly affected.

2. In the case of alloys containing less than 92 per cent copper, the tenacity and the elongation increase decidedly as

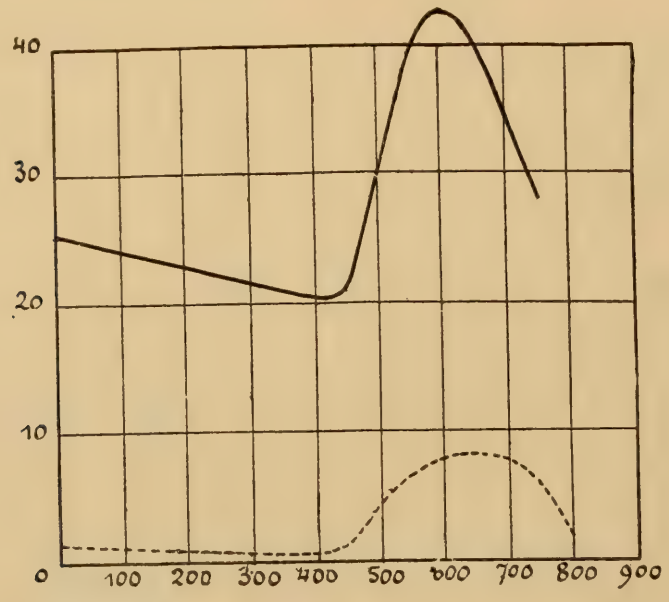


DIAGRAM 12. Type 2. Cu, 84%; Sn, 16%

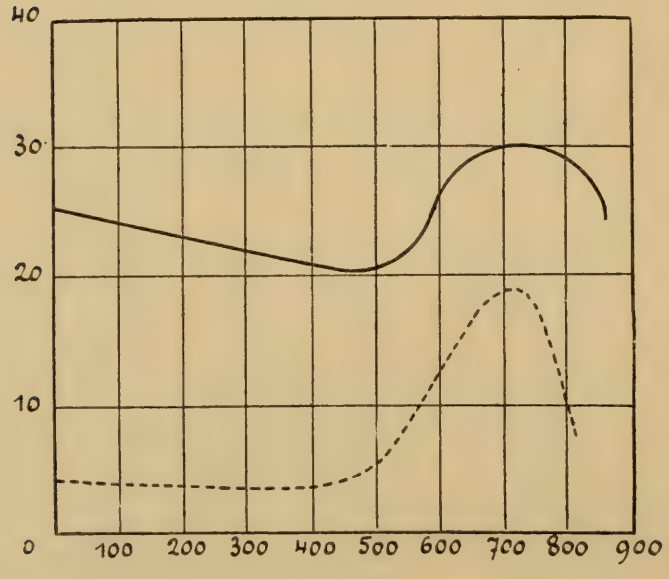


DIAGRAM 13. Type 3. Cu, 87%; Sn, 13%

soon as the quenching temperature exceeds 500°. This is in full accord with Messrs. Heycock and Neville's diagram.

Maximum strength is reached, whatever the composition, at a quenching temperature of about 600 degrees.

Maximum elongation on the contrary seems to be affected by the composition of the alloy. With 91 per cent copper, maximum elongation corresponds to a quenching temperature

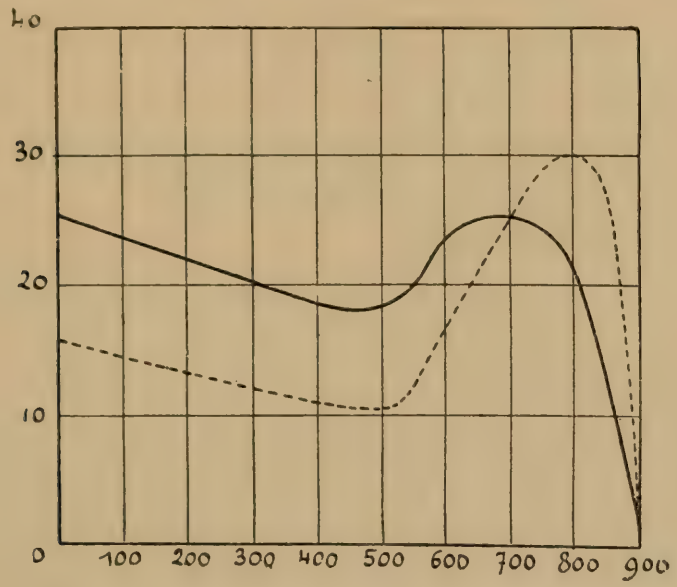


DIAGRAM 14. Type 4. Cn, 91%; Sn, 9%

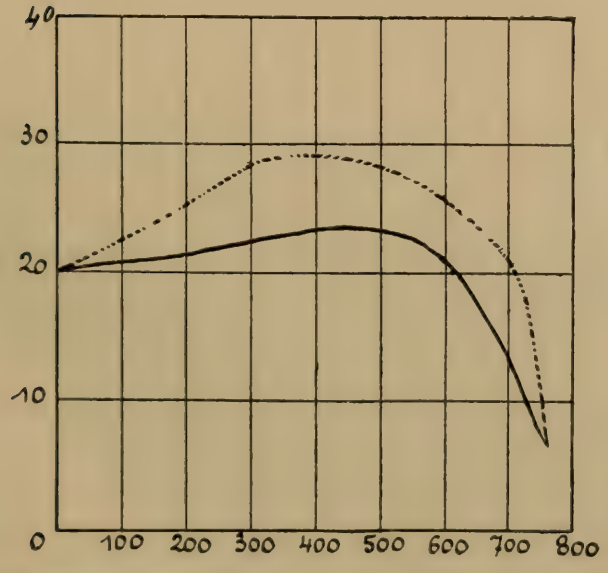


DIAGRAM 15. Type 5. Cu, 95%; Sn, 5%

of 800° while with 79 per cent the maximum elongation corresponds to a quenching temperature of 600°. The difference between the tenacity of the cast alloy and that of the metal

quenched at the most desirable temperature, is the greater the smaller the percentage of copper. It may be concluded from these results that the quenching of bronzes causes a decided improvement in the results obtained by tensile tests. It would be interesting to ascertain the effect of quenching upon the frictional properties of bronze, for it must be remembered that quenching causes the disappearance of the definite compound, a very hard substance, which must play an important part when the bronze is employed for bearing purposes. The writer hopes soon to investigate this point.

VANADIUM AND VANADIUM STEEL *

THE increasing importance of vanadium to the modern steel maker will render a résumé of the methods by which this metal has been obtained from its ores of interest to readers of "The Engineer." Of the rare metals which, alloyed with iron in steel, have most important effects upon the physical properties of the latter, vanadium seems to be the one by which the greatest effect is produced with a minimum addition of the element. There are, in fact, some well-known metallurgists who assert that the properties of Swedish iron and steel are due to the presence of vanadium oxide in the original iron ore from which this iron and steel is made; and the special characteristics of the latter are ascribed to the very minute percentage of vanadium which finds its way into the finished material, and is generally overlooked in the analysis of the same. There are, of course, other metallurgists who hold this view to be incorrect, and who believe that Swedish iron and steel owes its superiority to other causes.

However, whether this theory regarding Swedish iron and steel be correct or not, vanadium steel undoubtedly possesses physical characteristics which render it suited for special requirements. The following description of the methods by which vanadium and its alloys can be prepared from vanadium ores, and the résumé of the researches by Guillet and others upon the physical properties of the vanadium steels made from these alloys should therefore prove of value to modern steel makers.

* "The Engineer," June 9, 1905.

The presence of vanadium in a lead ore from Mexico was discovered by Sefström, a German chemist, in the year 1830, and the properties of the supposed new metal were investigated by Berzelius, the noted Swedish chemist, in the following year. Roscoe, in 1867, however, showed that the compound Berzelius had supposed to be the metal was in reality the oxide of the nitride, and that the properties he had ascribed to it were thus incorrect — the metal being allied in properties and characteristics to the arsenic and phosphorus group of elements, and not to the chromium group as Berzelius had supposed.

Vanadium occurs in nature chiefly in the form of compounds of the higher oxide V_2O_5, the acid being known as vanadic acid, and forming salts represented by the general formula, H_3VO_4, and called "vanadates." On loss of one molecule of water the vanadic acid becomes metavanadic acid, and the general formula for salts of this acid is HVO_3. Vanadium occurs in nature in many of the ores of lead and iron, and at one time a vanadium-bearing lead copper ore was mined in Cheshire. As already pointed out in the introduction to this article, the special properties of Swedish iron and steel are now attributed by some metallurgists and engineers to the presence of vanadium in the original ore from which it is smelted.

Pure vanadium was prepared by Roscoe in the chemical laboratory by heating the dichloride V_2Cl_4 in a current of hydrogen gas. The hydrogen combines with the chlorine and carries it off as hydrochloric acid gas, while the metal remains as a light gray metallic powder, having a specific gravity of 5.5. This powder does not oxidize or tarnish when exposed to the air, but it melts at about 1700° C., and when strongly heated in air it combines with oxygen and yields V_2O_5.

Minerals containing vanadium are found in Spain, Mexico, Sweden and Scotland, and probably now that the metal has become of considerable commercial importance, its presence in a large number of minerals and in various localities will be demonstrated.

Extraction of Vanadium from its Ores

Several methods of extracting vanadium from its ores have been proposed. Some of them are now in use upon an industrial

scale of operations, and the following notes give briefly the details of the more important of these:

(1) At the works of Bas Coudray, near Le Genest, in France, a Spanish ore containing lead vanadate is employed. This ore contains 12 to 14 per cent V_2O_5 and about 50 per cent Pb. The ore is first smelted for its silver and lead contents, with carbonate of soda and coal. The lead and silver are thus separated in metallic form, and the vanadium passes into the slag as sodium vanadate. The slag is then submitted to a melting temperature in another furnace, and air is blown over it to oxidize the vanadium and form vanadic oxide, V_2O_5. The molten slag is then granulated by running it out of the furnace into boiling water, and from this the vanadic acid is extracted by leaching in suitable tanks. Silica is removed from this solution by careful addition of sulphuric acid, and the vanadic oxide is finally precipitated by use of an excess of the same reagent. By use of ferric sulphate, or sulphates of other metals, in place of sulphuric acid, a mixture of vanadic oxide and ferric or other oxide can be precipitated. From these mixed oxides special alloys of vanadium and iron, nickel, copper or cobalt can be prepared by the Goldschmidt aluminum reduction process. Further details of this method of obtaining vanadium will be found in the original memoir by Herrenschmidt in "Comptes Rendus," 1904, p. 635, Vol. CXXXIX.

(2) Gin, the French electrometallurgist, has proposed a method of extraction which, in some respects, resembles that used for the electrolytic reduction of alumina; but in this case not pure vanadium, but an alloy of vanadium and iron, is produced. A bath of molten calcium and ferric chloride is prepared, and this is electrolyzed with an iron cathode and an anode composed of an intimate mixture of vanadium trioxide and carbon. The fluorine which is liberated at the anode attacks this oxide and forms vanadium fluoride, and this in turn is decomposed by the current with liberation of vanadium at the cathode. This cathodic vanadium then combines with the iron produced by the decomposition of the ferric fluoride, and an alloy of iron and vanadium is finally obtained in the molten state on the floor of the bath. A current density of six amperes per square centimeter at the cathode is required with an electromotive force of 10 to 15 volts.

The following chemical equations represent the three steps in this process of manufacturing ferrovanadium alloys by electrolysis:

(1) $Fe_2F_6 = 2\,Fe + 6\,F.$

$-$ at the cathode; $+$ at the anode

(2) $V_2O_3 + 3\,C + 6\,F = 2\,VF_3 + 3\,CO.$

(3) $2\,VF_3 = 2\,V + 6\,F.$

$-$ at the cathode; $+$ at the anode

Further details of this method will be found in the paper read by M. Gin before the Fifth International Congress of Applied Chemistry at Berlin in 1903.

(3) Carpenter, an American metallurgist, has patented the following method of smelting ores containing vanadium trioxide, in order to obtain ferrovanadium alloys. The ores, which may contain .5 to 5 per cent of vanadium, and much silica, alumina, etc., are smelted by the ordinary blast-furnace procedure, in the presence of a sufficient amount of iron oxide, to produce the iron required for the final alloy. The fuel and blast must be arranged to produce a very high temperature together with a very strong reducing action, and the iron oxide must be intimately mixed with the vanadium-carrying ore, in order to insure that iron is present at each point where vanadium is liberated. Dolomite or some other basic flux is added to slag off the silica, when this is present in very large amounts. This method is covered by a United States patent, No. 781,808 of 1905.

(4) Goldschmidt uses the following method for preparing alloys of vanadium and aluminum. The oxide of vanadium, perfectly dry, is intimately mixed with powdered aluminum in calculated amount. A small portion of this mixture is now introduced into the type of reducing crucible used for this work, and the reaction is started by a sodium-peroxide cartridge and a red-hot iron, in the customary manner. The remainder of the charge is then projected in small portions into the crucible as the reaction proceeds and an alloy of vanadium and aluminum is produced under the slag of fused alumina. The propor-

tion of vanadium in this alloy can be varied at will, but one containing 20 per cent of aluminum is the most convenient for use.

(5) Moissan attempted to reduce vanadium oxide directly by carbon, in his early experiments with the electric furnace. The reduction took place very slowly, and even with a current of 1,000 amperes at 70 volts an impure product containing much carbon was obtained.

Details of this experiment will be found in "Comptes Rendus," Vol. CXVI, p. 1225, and also in Moissan's classical work on the electric furnace.

(6) Von Bolton, in the laboratory experiments for Messrs. Siemens and Halske which have resulted in the new tantalum incandescent lamp, carried out some investigations upon the reduction of vanadium trioxide which may be referred to here.

The brown oxide powder was intimately mixed with paraffin and was made into rods, which were then embedded in granular carbon and heated to a temperature of 1700° C. The hardened and compact rods of vanadium trioxide, .8 millimeters in diameter, which remained after this treatment, were then placed in a vacuum apparatus and were electrically heated with a current of 1.8 amperes at 42 volts. Much oxygen was given off as the rods became white hot, and this was carried off by continuing to work the vacuum apparatus. The metallic gray mass which remained was composed largely of pure vanadium, and had a melting point of 1680° C. This metal was not used, however, for the new lamp, since its melting point was 550° C. lower than that of tantalum.

Properties of the Vanadium Steels

1. Guillet, the well-known French chemist and metallurgist, has published several researches bearing on the properties of the vanadium steels. The results of the first of these were presented to the French Académie des Sciences early in 1904, and were published in "Comptes Rendus" of February 8, 1904. They dealt with two series of steels containing a variable percentage of vanadium, with high and low carbon contents. The addition of vanadium was found to alter the physical structure of the steel, the results being as follows:

Structure	No. 1 Series	No. 2 Series
	Carbon .10 to .20 per cent	Carbon .60 to .85 per cent
Pearlite only	Up to .70% vanadium	Up to .50% vanadium
Pearlite and double carbides	From .70 to 3.0% vanadium	From .50 to 7.0% vanadium
Double carbides only	From 3.0 to 10.0% vanadium	From 7.0 to 10.0% vanadium

The pearlite steels were not more fragile than ordinary steels, but were harder, while the double carbide steels were low in tensile strength and brittle. The steels containing both pearlite and double carbide occupied an intermediate position, as regarded strength and hardness.

A steel containing 1.04 per cent vanadium and .112 per cent carbon gave the highest tensile strength in the first series, namely, 61.1 kilos per square millimeter, while one containing 4.99 per cent vanadium and 1.084 per cent carbon gave the highest strength test — 98.9 kilos per square millimeter — in the second series. In a further communication to "Comptes Rendus," dated August, 1904, Guillet states that the steels containing a high percentage of vanadium are of particularly irregular strength and structure, as the light carbide of vanadium tends to float when the metal is being cast.

The general conclusions of Guillet, based upon these series of tests, were that only those steels containing less than .70 per cent of vanadium could be considered of industrial value. The brittleness of these steels, however, rendered them unsuitable for use in the manufacture of cutting tools, and, in the author's opinion, another series of investigations were required to decide whether this brittleness could be overcome by the use of nickel with the vanadium. This investigation Guillet intended to undertake when opportunity offered, but up to the present no results of this new investigation have been published.

2. Capt. H. R. Sankey and Mr. G. K. Smith, in December, 1904, read a paper before the Institution of Mechanical Engineers, upon "Heat Treatment Experiments with Chrome-Vanadium

Steel," which contained much valuable information relating to the effects of heat upon steel containing vanadium and chromium. This paper and the discussion upon it were fully reported in "The Engineer," of December 23, 1904. The authors used in their experiments a raw chrome-vanadium steel, the exact composition of which was not stated. This steel showed a tensile strength of 54 tons per square inch, and, at the same time, behaved under bending and twisting stresses like mild steel of the highest quality. Its power of resisting torsional strain was also stated to be enormous — a piece 6 inches in length and .75 inches in diameter twisting 3.9 times before parting.

3. A series of tests have been made by Professor Arnold of Sheffield, and other metallurgists, upon the steels produced from the special ferrovanadium alloys made by the New Vanadium Alloys Company, Limited, of London, and of Llanelly in South Wales. The results of these tests have been published in "The Engineer" of July 1 and September 2, 1904, in letters signed by A. F. Wiener, the managing director of the company.

The most important tests of this series showed that the tensile strength of plain steel containing .25 per cent C., and .40 per cent manganese was raised from 30 tons to 47 tons per square inch by the addition of .25 per cent vanadium, and that a similar addition in the case of a nickel steel raised the tensile strength from 42 to 68 tons per square inch.

The highest figure attained in these tests was for a nickel vanadium steel of the following composition: .141 per cent C., .512 per cent manganese, 9.36 per cent Ni., and .29 per cent V. This stood 101.20 tons per square inch before parting in the testing machine, as compared with 88.8 tons, the previous record for nickel steel.

As a result of the above test, Professor Arnold stated that "it was demonstrated beyond doubt that the addition of a few tenths per cent of vanadium raises the elastic limit of mild structural steel at least 50 per cent without seriously impairing its ductility."

METAL MIXERS FOR PIPE FOUNDRIES *

By J. B. NAU, New York

SOME time ago the writer had an opportunity to take a trip through some of the most modern European foundries and noticed that in many respects these foreign foundries are ahead of American practice. This was more especially to be seen in pipe foundries. The pipe specifications of Europe, while very strict and exacting in many ways, in fact more so than in the United States, leave the manufacturer some latitude not enjoyed here. This is especially true in regard to the iron used. Whenever possible, for obvious reasons, the European manufacturer makes use of direct metal from the blast furnace. Of course every precaution is taken always to obtain an even quality of iron by mixing the metals running from the different furnaces in special ladles, or in mixers of special design that can be run from one furnace to the other. The principal aim of the manufacturer is naturally to give full satisfaction to the buyer, who, as is proper, insists that the pipe bought shall fill all the conditions of the specifications in regard to physical tests and strength of the metal. The buyer on his side insists simply on the pipe coming up to the specifications and leaves the manufacturer unhampered as to the source from which he should take his iron.

From long experience the manufacturer is well aware that he can satisfy all physical tests with iron whose analysis may vary within certain limits and that he can obtain the right quality either by mixing the iron from different blast furnaces or, if necessary, by correcting this direct metal by admixing a certain amount of metal melted in the cupola. This item of quality is generally very carefully attended to and the pipes made, especially in some of the most improtant French and German plants, where the best working methods in other respects are employed, is invariably of good quality.

It can be readily understood that the use of liquid metal directly from the blast furnace is fraught with many difficulties and its indiscriminate use is liable to produce pipes of uneven

* A paper read before the American Foundrymen's Association, New York, June, 1905.

and uncertain quality. That this is so is well illustrated by the fact that the American pipe specifications, in order to eliminate the factors of uncertainty and of uneven quality, prohibit the use of direct metal in the manufacture of pipes, and specifically state that the iron should be remelted in a cupola or an air furnace. Of course this remelting leaves no excuse to the manufacturer in regard to the quality of his iron, but still it has disadvantages that cannot be overlooked, one of which is the greatly increased cost of the iron when thus remelted. Another disadvantage lies in the danger of deteriorating the quality of the iron to some extent by increasing its sulphur content from the contact with fuel or flame. The best and cheapest way would naturally be to follow the practice already described, by mixing the different brands of irons running from the various blast furnaces and, if necessary, to correct the quality of the irons so mixed with irons remelted in the cupola. Such a proceeding, prohibited by American specifications, is only possible where the foundry is built near the blast furnace. Foundries not so located are naturally excluded.

Still, in order to get all the benefit that the use of direct metal would undeniably afford and yet avoid all the danger of the uneven quality, that alone guided the framers of the American specifications in prohibiting the use of direct metal, the use of a heated mixer of sufficient capacity is here recommended. A few years ago such mixers were introduced in Europe in connection with steel works and they give the very best satisfaction. The writer had occasion to see one such heater of a capacity of 250 tons in a basic Bessemer steel works. It was heated with producer gas and provided with regenerators. Such a mixer is more to be considered in the nature of a gas-heated air furnace, with the exception that the iron, instead of being melted in it, is brought liquid from the blast furnace and poured into the mixer, where it can be kept hot and liquid for any desired length of time.

Heated Mixers Preferred

Since the steel works find that heated mixers give such good satisfaction, why should the foundrymen not follow in the same steps wherever it is possible to do so? The small non-heated mixer that the writer saw in some German pipe foundry

gave good satisfaction and the iron could still be used after two hours' waiting. Heated mixers would give better satisfaction undoubtedly. Under the action of the flame, which must be of a slightly oxidizing nature, some undesirable refining of the iron would take place and a small part of the silicon and manganese would be burned out. But as the iron is poured liquid into the mixer the oxidation of silicon and manganese would be much less than in the air furnace or the cupola, where from one quarter to one third of the silicon is burned out, mostly during the melting period. In this respect the heated mixer, where no melting is done, should be far more advantageous.

But it has other advantages. It is a well-known fact that the mixer as such is an excellent apparatus for eliminating in a short time a large percentage of the sulphur contained in the iron. In fact, this elimination reaches easily 50 and 70 per cent. The quality of the iron will, therefore, be considerably improved in the mixer. In the cupola the contrary always happens.

Since the metal can be kept hot to any degree in the mixer, this affords us means to correct at once the quality of the metal by throwing and melting in it whatever cold pig may be necessary to obtain the right analysis.

Thus the use of the heated mixer for foundry purposes in connection with the blast furnace would seem to present very marked advantages:

1. It would allow the use of direct metal from the blast furnace, thereby saving the remelting cost, which is always high.

2. It would afford an easy and cheap means of eliminating a large percentage of sulphur, thereby, contrary to cupola practice, improving the quality of the iron.

3. It could be used directly to correct the quality of the metal by melting in it a certain amount of cold pig iron, with probably less cost than when the melting is done in the cupola and with certainly less absorption of sulphur during the melting, because the solid pig will melt in the liquid bath and be removed from contact with the flame.

Naturally such a mixer could be used for other than pipe foundry purposes when proximity to the blast furnace allows its adoption. It would even allow an independent large foundry to use liquid iron from a nearby blast furnace belonging to another company. Both companies would benefit by the practice.

Features of European Pipe Foundries

Coming back again to European pipe foundry practice, which led us to the above consideration of mixers, many other improved methods are applied, all tending toward a general cheapening everywhere. What one notices first in the most modern European pipe foundries is the complete absence of pits. The molding and pouring are done on an upper floor to which one half of each pipe flask is fastened; the other half is left free to be slid back. The flasks are never taken from their place. The finished pipe alone is lifted up by the crane, which having less weight to lift can be lighter than would otherwise be the case. The lower end of the flask hangs freely down to within a certain distance of a lower floor and is accessible from every side. The drying of the flasks is done by means of producer gas or even blast-furnace gas. The producer gas is made in gas producers situated outside the works and let through underground gas flues underneath the rows of flasks. Here special burners, varying in the different foundries, are used to dry each flask thoroughly and rapidly. In most places gas is also used to heat the core ovens. These arrangements also vary in different places.

In one foundry in eastern France, where coke is very expensive (fully $5 a ton), special arrangements are made to burn coke screenings from blast-furnace coke in the core ovens. The use of this fine coke, otherwise lost, was the cause of a very great saving in the drying of the cores. After the pipe is cast the sand falls from the flask and is taken up by conveyors, and after being cleaned and screened is taken by conveyors to the top floor, where it will be used again in the ramming of the flasks. In some foundries the flasks are put up exclusively in straight parallel rows; in others, especially for pipes of less than 25 inches diameter, revolving pits or drums are used, somewhat similar to what is done at the Chattanooga plant.

In the case of revolving systems the drying of the flask is also obtained with gas. Some very ingenious drying appliances are used in these systems. Tarring appliances also are very modern and of an improved style. In fact, the work everywhere is reduced to a minimum.

MELTING STEEL WITH CAST IRON*

By R. P. CUNNINGHAM, Holyoke, Mass.

THE demand for castings to stand great strains has increased to such an extent that foundrymen are often at a loss how to produce castings up to the required specifications. The manufacturers who are the most often called upon to produce castings of high strength are pump and engine builders, tool makers and car-wheel manufacturers. With pump builders a few years ago it was something very unusual to receive an order for a pump to stand a pressure of more than 1,000 pounds. To-day it is nothing uncommon to get an order for a pump to work under a pressure of 5,000 pounds, and even higher. Engine builders are called upon to build engines to work under 200 pounds steam pressure, while only a very few years ago 100 pounds pressure was considered about the limit.

I might say the same thing about tool making. The speed at which the modern tools are run to-day is nearly double that of a few years ago. Look at car wheels and compare the tests they are subjected to to-day with those required twenty-five years ago. The increase is over 100 per cent. Yet car wheel makers have managed to make wheels that come up to the requirements. I might go on and enumerate many other branches of the trade that are doing what was once considered an impossibility. This goes to show that the foundrymen of to-day are alive to the requirements, and yet we often hear men say that the foundry has not progressed as fast as other branches of manufacturing. On the contrary, considering the attention that has been paid to the foundry, we have managed to make castings that have been far above the specifications called for. Foundrymen do not always have the iron in their yards to make castings of any required strength, but by a judicious use of steel scrap we can produce castings of the strength desired.

Any one familiar with pump work will readily understand the necessity of having a perfect casting, not alone smooth and true to pattern, but clean, close grained, yet soft enough to machine easily. Many castings go through the machine shop and

* A paper read before the American Foundrymen's Association, New York, June, 1905.

erecting room, but fail when put under test. This adds to the manufacturing cost, as often the machining is many times the cost of molding. By adding a percentage of steel scrap we have in a great measure overcome this difficulty if the trouble is caused by porosity of the metal.

Care in Charging the Cupola

When melting steel with cast iron there are many things that require close attention in order to obtain the very best results. In charging the cupola one cannot be too careful and should be absolutely certain that all the material called for in the charge is put in. The weight of each material specified should be correct; the fuel and fluxes should be analyzed so that the exact composition of all the materials going into the iron to be made may be known.

In making high-grade metal we have to contend with the impurities of the fuel and fluxes charged into the cupola besides that we have estimated on in the metal. All impurities in excess tend to weaken the metal in tensile and transverse strength; for this reason there is more difficulty in making a successful cast when using a large percentage of steel scrap.

A high percentage of steel necessarily increases shrinkage, demands closer attention, requires more rapid handling in the foundry and when very high tends to make all the operations connected with it draw away from those of a cupola metal and approach that of a steel casting. When this extreme point is reached melting in the cupola becomes very unsatisfactory.

The average thickness of a casting bears a relation to the percentage of steel desirable. For thin castings only a small percentage can be used, while for thick, heavy castings a large per cent is permissible. This is so because a thin casting has no self-annealing power, on account of its rapid cooling and the chilling effects of the mold. The thicker casting, on account of its slower cooling, anneals itself somewhat and opens the grains of the metal perceptibly. The same metal in a thin casting, which is hard, would be quite soft in a heavy casting. My opinion is that it is more desirable to have a mixture with the smallest percentage of steel that will give sufficient strength and solidity to the casting for all practical purposes.

We sometimes doubt the wisdom of the engineer when he calls for castings that will stand so many thousand pounds to the square inch, because the metal that will stand the highest test in the bar is not always the most desirable. It may be brittle or flaky, with no elasticity, and yet test high. What we aim for in practical foundry work is a high-grade metal that will stand a fairly high test and machine easily. It is this kind of a casting that can be made with a percentage of steel scrap melted with your iron, provided the rules are accurately followed.

My method of charging a cupola is as follows: Let us say that we want to make a casting which will require 4,000 pounds of metal, with 25 per cent steel. With a cupola that lines up 48 inches, we put on the bed 1,200 pounds of coke, on top of this put 1,000 pounds of iron, then 500 pounds of steel, then 500 pounds of iron, then 150 pounds of coke, 500 pounds of steel, 1,500 pounds of iron. The coke next above the metal charge should be greater than between the ordinary charges, and the pig iron in the next charge above the steel should be of the same chemical analysis as the iron used in the steel, so that if any metal should melt and run into the steel it will do no harm. With the last amount of steel we add $1\frac{1}{4}$ pounds of ferro-manganese to every 100 pounds of steel used. We also put the same amount of ferro-silicon into the ladle. This should be done after the first metal has been drawn into the ladle. This metal should be poured as soon as it becomes quiet in the ladle.

If the casting is uneven in thickness attention must be given the shrinkage. Setting a riser on the heavy parts and after the mold is full pouring slowly until the riser is full obviates trouble. If the casting is very heavy it will be necessary to feed it, but an ordinary casting will not require this.

Selection of Pig Iron and Scrap

We have found by using two brands of iron, one high in manganese and the other high in silicon, both low in sulphur, that we can get a much finer grained casting, with more elasticity, than we could if we depended on ferro-manganese and ferro-silicon to bring these two elements up to the desired percentage. I reason it in this way: If the manganese and silicon are in the pig they are more evenly distributed than when they are put

into the cupola and depended upon to become thoroughly mixed in it or in the ladle. We have never yet depended upon the pig for the entire amount of manganese or silicon wanted, but have added each in the proportion given above. We sometimes have trouble caused by wrought scrap or hard steel becoming mixed with the steel scrap. In either case satisfactory results cannot be obtained. With hard steel there are hard spots in the casting, while wrought iron increases porousness, which is very bad if the casting is uneven in thickness.

My opinion is that mixtures of this kind will be used in the future to a greater extent than in the past because the demand for this class of castings has increased and foundrymen will readily see that by this means they can build up their present mixtures to show greater strength and other desired qualities.

The result of 18 casts with different percentages of steel showed that the highest amount of steel that could be used to advantage is 33 per cent. Above this showed excessive shrinkage and only slight gain in strength. The highest point reached for tensile strength was 33,205, the lowest 31,890, for perfect bars. The highest transverse strength shown was 3,335, the lowest for a perfect bar was 3,180. Six bars were cast from each heat, two at the first part, two in the middle of the heat, and two at the end. In every case the two bars cast in the middle of the heat showed up best in tensile and transverse strength. The first bars were not uniform and showed small pin holes. The last bars showed up badly in every instance. Less trouble will be had with less than 33 per cent than above that amount of steel scrap in the gray iron mixture.

For ordinary work 25 per cent of steel will give sufficient strength for all practical purposes, will machine easily and yet be close grained. This is the per cent I would recommend foundrymen to use unless it is for some special work.

RAIL SECTIONS AS ENGINEERING STRUCTURES*

By P. H. DUDLEY

THE mechanical properties, as stiffness and strength of a section, increase in a rapid ratio as the height is augmented, as shown by Table No. 1.

TABLE NO. 1

Weight of Section in pounds	Height in inches	Width of Head	Moment of Inertia, fourth power, inches	Moment of Resistance, cubic inches
60	4.0	$2\frac{1}{4}$	12.0	6.7
65	4.5	$2\frac{3}{8}$	16.0	7.8
80	$5\frac{1}{8}$	$2\frac{21}{32}$	28.3	11.4
100	6.0	3.0	48.5	16.6

The 80- and 100-pound sections become more efficient engineering structures than the 60- and 65-pound which they replaced, by inducing a longer distribution of the passing wheel loads to the cross-ties and ballast, and lessening the deflection under the wheels. A greater portion of the wheel effects is absorbed by the constraining negative bending moments in the wheel spacing, reducing the positive moments under the wheels. This favorable action for a smoother running surface in the general depression under the wheels, however, increases the wheel contact pressure intensity per square inch in the bearing surface of the section, and imposes a greater burden upon the metal of the entire head.

The stiff sections for a given unit fiber strain carry larger bending moments than the limber rails, and therefore are more efficient engineering structures for heavier axle and total loads.

TABLE NO. 2

POSITIVE BENDING MOMENTS IN INCH-POUNDS FOR THE GIVEN UNIT FIBER STRAINS PER SECTION IN TABLE NO. 1

Section	10,000 lbs.	20,000 lbs.	30,000 lbs.	40,000 lbs.
60 lbs.	67,000 I. lbs.	134,000 I. lbs.	201,000 I. lbs.	268,000 I. lbs.
65 ,,	78,000 ,,	156,000 ,,	234,000 ,,	312,000 ,,
80 ,,	114,000 ,,	228,000 ,,	342,000 ,,	456,000 ,,
100 ,,	166,000 ,,	332,000 ,,	408,000 ,,	664,000 ,,

* Presented at the June, 1905, meeting of the American Society for Testing Materials.

In the 80- and 100-pound sections nearly the given maximum moments have been obtained in tests.

Unit fiber strains in tension from .0 to 30,000 pounds are those which occur daily under present locomotives, with some strains of the higher figures and liable from a flat wheel to be exceeded.

Large unit fiber strains have been common since steel has been used for rails, for the limber sections had frequent sets, which indicated they were strained beyond their elastic limits.

Under 65-pound rails in a yard track, a unit fiber strain has been measured of 56,000 pounds.

The elongation for the unit fiber strains in Table No. 2 would be .00034, .00067, .001 and .00134 of an inch respectively, for the modulus of steel at 30,000,000 pounds, summer temperatures, though the modulus is higher in the winter.

The height of the section is increased to augment the mechanical properties of stiffness and strength. This has a tendency to reduce the unit fiber strains in the base of the rails, but the subsidence of the roadbed under the wheel loads, the looseness of the cross-ties in the ballast, and the rails under the spikes, cause the bending moments carried by the stiff rails to exceed those by the limber sections for the same wheel loads, though the percentage distributed per individual cross-tie is less. This reduces the area of contact and increases the intensity of the wheel pressures per square inch in the bearing surface. The wheel loads also have been doubled on the stiff rails, over what they were on the light sections, and the metal in the bearing surface, therefore, sustains two and three times the burden required by the former limber sections. (See Vols. III and IV of the Proceedings, for Unit Fiber Strains and Bending Moments.)

To carry the trains and distribute the wheel loads, the rail section has the top of the head or bearing surface shaped for the wheel treads, to receive their pressures and distribute the loads to the cross-ties, ballast and roadbed. The side of the head of the rail is the guide for the passing wheel flanges, while the entire section becomes the girder to distribute the wheel loads.

The metal in the rail section has three functions to perform, to receive support, guide and distribute the wheel loads of the passing trains. First, the metal in the bearing surface sustains its loads principally by its properties of cubic elasticity, and

should be sound and homogeneous. Second, the side of the head resists abrasion of the wheel flanges by its toughness and tenacity. Third, to distribute the loads by the entire section its linear elasticity is exercised.

The factor of safety in the girder determines what physical properties may be used for the bearing surface and guide.

The metal in the head of the rail must receive and sustain the wheel contact pressures by its cubic elasticity, but distributes the loads through the section as a girder, by its linear elasticity.

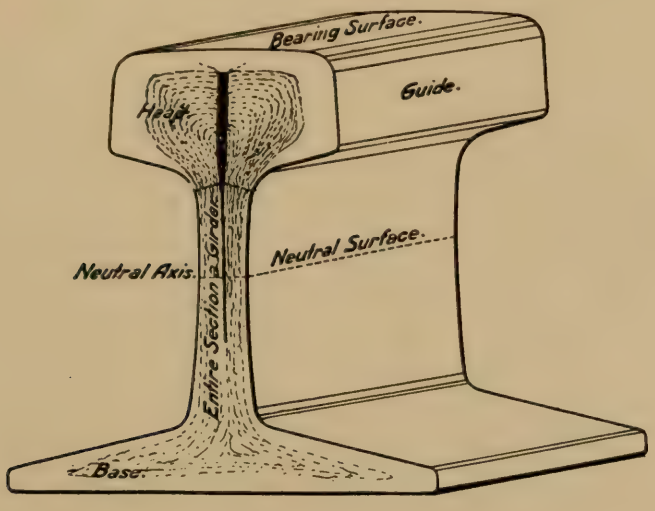


FIG. 1. A Rail Section from the upper portion of the ingot with a central core of metal in which by liquation the metalloids in the steel are above the average. A central pipe is also indicated, which may be formed without decided liquation.

The distortion of the rail head in service shows that the steel has low limits of cubic elasticity, and is not homogeneous. (See Figs. 1 and 2.)

When the steel is solid, sound and of fine texture, the head does not become distorted under the service, though it wears in the bearing surface and on the side. When the ingot is unsound and spongy, then the head flattens and crushes under the wheel treads. Rails from the top of the ingots, where by liquation the upper portion contains a higher percentage of carbon and phosphorus, the central core of metal is not sound and strong, but fragile, and does not sustain the wheel contact pressures as well as the exterior portion of the section. (See Fig. 1.)

When a decided pipe in the ingot did not occur in cooling, the repeated pressures of the wheel contacts develop a check which is equivalent to a pipe, the metal immediately over it in the bearing surface stretching sidewise by its linear elasticity; the check widens until a portion of the head becomes detached from the web of the rail, unless removed from the track. (See Fig. 2.) The steel in the head is not homogeneous, either in quality or structure, and becomes distorted as a section, from inadequate physical properties of cubic or elasticity of volume, to sustain and distribute the wheel loads.

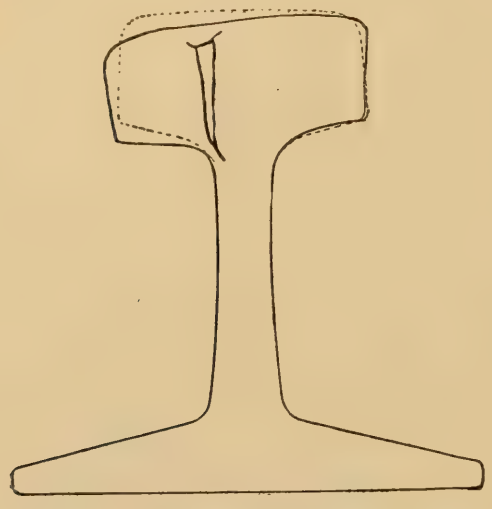


FIG. 2. Check developed in head of rail, twelve feet in length, after service. Sound at the ends.

The splitting of the head in the earlier steel rails was in nearly all cases traced directly to a pipe in the ingot. These conditions still exist, yet there are numerous instances in which the pipe did not develop in cooling, but does in service, in the unsound metal of the central core of steel, as indicated in Figs. 1 and 2. Pieces break from the side of the rail head, in steel where so decided liquation has occurred in the ingot as to make two or more grades of steel in the rail head.

The changed relations of the steel are not appreciated in the bearing surface to the wheel contact pressures in the stiff sections, as the efficient engineering structures which have empowered the present wheel and total loads of the locomotives and cars. By the design of the section for a given weight, its mechanical properties have been increased to transport heavier loads. To complete it as an engineering structure, with the requisite efficiency, the physical properties must also be augmented in sound metal, to raise the limits of its cubic elasticity in the bearing surface proportionately to those required by its enlarged mechanical properties as an engineering structure, — a question of mechanics, involving a metallurgical solution.

Iron rails failed in the bearing surface when the wheel loads

increased to 10,000 pounds, owing to low limits of cubic or elasticity of volume of the metal. The two or three per cent of slag made it a bundle of fibers only for the wheel pressures, though adequate to distribute the loads as a girder. Increase in stiffness in the iron rails to carry larger bending moments hastened their destruction.

In the limber steel rails first rolled, the grain or texture of the metal was fine and compact; the elastic limit in reference to its cubic elasticity was high, and could sustain the wheel contact pressures without distortion. The conversion of the steel was less rapid, the ingots smaller, and liquation was slight. The present conversion, in larger vessels, teemed in larger ingots, are not as sound, for the entire length, as the smaller ingots. The tendency of the upper portion is to form a pipe or become porous, or from the longer time in cooling, allows the metalloids to separate from the bath and become concentrated in an upper central core of the ingot. This does not produce homogeneous metal in the head. It is not capable of sustaining the wheel contact pressures by its cubic elasticity, and fails rapidly in service.

These are important problems in the manufacture of rails for the present service. It is not alone a question of heat treatment, a necessary, yet an over-estimated, panacea for defective steel, but to secure a sound ingot, so that the metal in the entire head will be homogeneous.

The steel in the rail section should be sound and have sufficient physical properties and rigidity of structure to preserve the shape of the section under the traffic, except the loss by wear of the wheel treads in the bearing surface, and the wheel flanges on the side of the head. Sound metal of 56,000 or more granulations per square inch, and elastic limit of 56,000 to 60,000 pounds, has sustained the present wheel loads without distortion of the heads. The facing ends of the rails should not flatten in sections having moments of inertia of more than twenty-five fourth-power inches. More limber sections are not finished sufficiently secure to prevent the wear of the facing ends of the rails under the shocks of the present wheel loads.

I have under observation rails made at several different mills; and in those without effort to control or check liquation, the splitting and the piping of the rail heads is pronounced.

In rails rolled from metal where attention was paid to checking liquation, the piping of the rail heads is practically unknown. The problems of checking liquation in large ingots are not always easy of solution and must be solved in reference to the practice of each mill.

The metal for the stiff rails, the efficient engineering structures, must be sound for any section to stand in the track without distortion under the traffic. If the steel contains a central core of harder material than the outside, or is porous, containing occluded gases, then it does not have sufficient toughness and tenacity of structure for the requisite limits of cubic elasticity to sustain the wheel load effects without distortion, and fails mechanically as an engineering structure.

HARD CAST IRON: A THEORY OF ONE OF ITS CAUSES *

By HENRY SOUTHER

A CONSULTING metallurgical engineer in contact with machine shops is accustomed to hearing complaints from the operators of machine tools of hardness of material being machined. Sometimes it develops, especially with steel, that the trouble is not that the steel is hard; but, on the contrary, that it is exceedingly soft. The softness is of such a character that the edged tool does not succeed in cutting the steel keenly, but rather tears it off, some of the particles clinging to the edge of the tool, causing excessive friction and rubbing, and drawing the temper of the tool, and dullness soon follows. The effect, as far as the machine operator is concerned, is that of a hard steel; the tool is spoiled. This not only applies to low carbons but to a peculiar physical condition of higher carbons, say, in the neighborhood of .50, due to bad annealing.

Then there is the legitimate hard steel, which is really hard in the true sense of the term.

Cast iron that chills may be called hard in the truest sense of the word. That is the complaint that is most often met when the term hardness is used in connection with machining cast iron. Iron chills because of high sulphur or low silicon, or a

* Presented at the June, 1905, meeting of the American Society for Testing Materials.

combination of both, and machine tools simply cannot cut it. This kind of hardness is more often found in thin work than in thick work. For example, the hardware people casting very thin material have to use the softest of iron, high silicon and low sulphur, in order that the small amount of machining they do may be done at all.

In the last five or six years three separate complaints of hard iron have reached the writer and proved of so baffling a character that in each case visits were made to the machine shops working the iron and the complaint carefully investigated. Analysis or test did not reveal the cause.

The most instructive case covers them all. This instance was most instructive because it occurred on a multiple drill where several different sizes of standard drills were used and several thicknesses of metal were involved. On approaching the machine it was noticeable at once that there was trouble, because the drills were screeching in an unusual way.

It developed that small drills, $\frac{1}{4}$ inch or thereabouts, were standing up with this iron just as well as any other, but the larger drills in the neighborhood of $\frac{1}{2}$ inch and $\frac{3}{4}$ inch were dulling exactly as though the iron were charged with emery. The edges were being ground off and would only last a small fraction of the time usual for the same drills in the same machine.

Here was an unusual condition, — thin iron working easily; thick iron on the same castings working with difficulty.

The chemical results were normal, except manganese: silicon 2.50, phosphorus .70, sulphur about .080, total carbon 3.50 and manganese .16.

The fracture of the iron was good, and moreover it was quite normal as far as could be seen with eye or microscope. A Keep's test drill was used, and developed nothing unusual, no signs of hardness, thick and thin iron showing a normal curve. There was no opportunity to test the tool-wearing qualities on the Keep machine, because the drill was sharpened after every hole drilled.

Inasmuch as the only abnormal part in the analysis was shown in the manganese, that element was suspected, although there seemed to be no metallurgical reason for so doing. Means were taken to raise it to the neighborhood of .50, and as soon as

this was done the difficulty disappeared in the machine shop and has not reappeared after some months.

It is a complaint which reached me, as I said above, from two other sources, and in both of these sources the complaint was described by the machine shop people by saying that the iron was gritty. They were fully convinced that there was sand in it, but examination showed that to be out of the question and the iron was as clean as any iron.

This leads me to believe that there must be some carbide of iron or carbide of silicon that forms in the absence of a reasonable amount of manganese, and that does not form with manganese present. What this chemical combination may be I cannot surmise, but the problem presented is an interesting one from a theoretical and practical standpoint. Apparently its cure has been found, but the question remains, — Why?

The actual castings causing this trouble were put through and no specimens kept, so that the writer can furnish no samples for study, but this is doubtless something that comes before the other members of the Society; and although specimens may not be easy to get, they can doubtless be found.

ETCHING OF HIGH CARBON STEEL *

By E. H. SANITER

HAVING experienced considerable difficulty in getting etchings of high carbon steels, especially if in the tempered condition, with iodine, 2 per cent nitric acid or picric acid, I tried Sauveur's method of dipping in strong nitric acid (1.42 Sp. G.) and washing at the tap. This gave better results but required several treatments to get the desired etching. I then tried dipping the specimen in absolute alcohol, then in strong nitric acid and then washing at the tap. This gave a very good etching with only one treatment. The precaution must be taken to move the specimen about in the acid rapidly to get an even attack; to do this I hold the specimen in a pair of forceps. It is also necessary to use fresh nitric acid for each etching.

* Received July 17, 1905.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

THE Application of Dry-Air Blast to the Manufacture of Iron. Joseph W. Richards. A discussion of the paper of Mr. Gayley read by title at the Lake Superior meeting of the American Institute of Mining Engineers. 8,000 w. — The following extracts clearly indicate the author's views regarding the causes of the great saving of fuel resulting from the drying of the blast.

"The whole question of the economy obtained converges towards the discussion of the generation of the heat necessary for smelting in the region of the tuyères. To generate this amount of heat for the requisite temperature, with the production of no more carbon monoxide than is necessary to achieve reduction of the charges above, is the direction in which economy is to be obtained. The efficiency of hot blast is due to exactly this reason, that it increases the smelting-power of the tuyère region without an increase in the carbon monoxide formed, and with a higher temperature of the gases in the tuyère region.

"In another view of the matter, furnaces are limited by lack of smelting power at the region of the tuyères rather than of reducing power in the upper part of the furnace, and any process which increases the former, without diminishing the latter below certain requisite limits, will strengthen the furnace at its weakest point and result in corresponding economy. The hot blast accomplishes this by the positive addition of heat bodily; the dry blast improves matters by saving some heat otherwise

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When ordering, both the number and name of the abstract should be mentioned.

lost in decomposing the moisture, thus also increasing the smelting power. The drying of the blast is the exact equivalent of extra heating of the blast, both in its immediate and in its ultimate effects, but with the additional benefit of increasing the regularity of the temperature, smelting power and general running of the furnace.

"The figures show an apparent increase of only 4.8 per cent in the efficiency of utilization of the heat generated at the tuyères for smelting purposes, but this is not the correct way to regard the matter. In the two cases quoted there is an equal smelting done for the burning of 75.3 kilograms of carbon at the tuyères in the one case and of 58.05 kilograms in the other, a clear saving of 17.25 kilograms of carbon burned at the tuyères per unit of pig iron and slag melted, or 22.9 per cent of the carbon consumed at the tuyères. This represents approximately, therefore, the total economy in fuel for the whole furnace. More important than that, however, it also represents increased speed of smelting, by the use of a constant blast. A constant blast burns a constant amount of carbon at the tuyères in a given time, but if the furnace can be made to smelt a unit of pig iron and slag with 22.9 per cent less of carbon burned at the tuyères, it should be expected, by using a constant blast, that the rate of smelting would be increased at least 22.9 per cent by the new conditions, provided, of course, that the quantity of blast, measured at standard conditions, was kept constant.

"A more logical way of viewing the matter of increased smelting capacity is to consider the conditions with the use of moist blast, and then to consider what would happen if the moisture were suddenly to disappear from the blast, and the 14,512 calories absorbed in decomposing it to be suddenly restored to the furnace. The result would undoubtedly be a sudden increase in the heat available, and a rise in temperature of the melted iron and slag. Suppose this rise of temperature of the products were counteracted by increasing the burden of the furnace to such an extent as to bring back the temperature of pig iron and slag to their primary state. When this condition of extra burdening had been reached, the temperature of the pig iron and slag would be the same as before removing the moisture, and the 14,512 calories would have been all absorbed in doing an increased amount of smelting. In the actual case, the 14,512

calories were not all saved, but 14,512 — 3,225 = 11,287 calories were, by removing 77.7 per cent of the moisture; and the burden was correspondingly increased to keep the quality of pig iron made the same as at first.

"I conclude, that since Mr. Gayley obtained an increase of 24.86 per cent, the views here advanced give a satisfactory explanation of the increased smelting power of the furnace, that the heat saved by absence of moisture is directly utilized for increased smelting capacity, aided furthermore by a higher heat potential which of itself alone would increase the smelting rate about 5 per cent, the two factors working simultaneously and necessarily interdependently towards the total effect.

"In conclusion it may be said that the increased efficiency obtained by Mr. Gayley could theoretically have been obtained by an increased temperature of blast alone, viz., by using the moist blast at 597° C. (1,107° F.), instead of at 382° C. (720° F.). Such an increase would produce the effects of quicker running and economizing coke to the quantity noted with dry blast, but would still leave the furnace subject to the irregularities inseparable from using ordinary air with its varying temperature and content of moisture. The increased regularity of running of the furnace and quality of product, due to uniform temperature of air supplied to the blowing engine and uniform temperature before the tuyères, is the fundamental economic justification for Mr. Gayley's innovation; the increased rate of driving and economy of fuel alone could be obtained more cheaply by increasing the capacity of the stoves." **No. 396.**

The Manufacture of Chilled Wheels. P. H. Griffin. "The Railroad Gazette," June 16, 1905. 4,000 w. — The following comments are extracted from this paper:

"The chilled wheel owes its origin to the peculiar high chilling property of iron smelted with charcoal in the blast furnace, which property is not possessed by iron smelted with coke. Of late years the use of non-charcoal irons and scrap has become quite general, and many chilled wheels have been put in service which have contained large percentages of such material. The use of steel scrap to harden, and ferro-manganese to toughen and give chilling properties, has established the use of such non-chilling irons, but the quality of chilled wheels has not been

improved by such practice. The indiscriminate delivery of scrap wheels in part payment for new wheels, and the consequent use of such scrap in making new wheels has gradually distributed the non-charcoal iron wheels throughout all wheels, and thus spread the undesirable metal in all directions. It must be remembered that every chilled wheel made is destined to a sort of reincarnation, so that it will probably go on to the end of time bearing in each successive life the burden not only of its own defects, but of those acquired from its fellows in the foundry cupola. The manufacture of charcoal pig iron is one of the oldest industries in this country. It has increased from year to year, particularly in the Lake Superior region. The present annual capacity of all charcoal furnaces in America exceeds 500,000 tons. The supply is, therefore, ample so far as requirements for chilled car wheels are concerned.

" The wheel made some years ago may have had its failings, but it certainly was made of better material than the average wheel of to-day, which is bound to progress toward a lower average quality of material, on account of the general practice of recasting old wheels into new ones, and the increasing use of non-chilling or non-charcoal iron and scrap. Railroads should buy, at least for special service, such as 50-ton car equipment, wheels made from new charcoal iron. It is not necessary to specify mixture or kinds of iron, but simply to provide for wheels of new charcoal iron. The additional cost will not be great. In the case of wheels bought at average prices the added cost should not be over eight to ten dollars per car.

" The possibilities of the chilled wheel for meeting conditions of service that are likely to arise in the future, lie in two directions. First, increase of strength and resistance to wear in the material of which the wheels are made and improvements in type and section of wheel. Second, improvements in methods of manufacture.

" The principal factors of value in charcoal iron for chilled wheel manufacture are strength in general, and hardness combined with wearing quality in the chilled surface obtained. By the use of special alloys some remarkable qualities of chilled iron have been produced. In the course of some recent experiments made by the writer, chilled metal was produced in which the crystalline structure was composed of what are known as

hair crystals. These crystals have no angles but interweave with and radiate from each other in a complex but perfectly ordered arrangement. The strength of this chilled metal is equal to that of the best crucible steel, and the increased strength is due to the process of chilling. This reverses the ordinary result when chilling occurs, which is, that brittleness is increased.

"There is not the slightest doubt that chilled wheels equal to and beyond any of the present demands of service can be readily obtained by railroads that are willing to pay for them. No more striking proof of what is practicable and indeed necessary in this direction can be afforded than by consideration of the fact that the entire net cost of wheels for a car is less than $25. Eight chilled wheels, 33 inches in diameter, weighing 600 to 700 pounds, less scrap value, which can always be realized at 50 per cent of first cost, will not exceed the net cost stated. This is less than 5 per cent of the average cost of the new car.

"The chilled wheel makers have certainly done their part in reducing the cost of building and operating American railroads, and there must be some limit to the further demands on them to produce still better results regardless of conditions." **No. 397. B.**

Power from Waste Furnace Gases. "Power," June, 1905. 3,800 w., illustrated. — The article describes briefly the installation of the Koerting two-cycle gas engines at the Lackawanna Steel Company's plant at Buffalo, N. Y., as well as some European plants. It concludes as follows:

"The power available from the waste gases in a blast-furnace plant is known to be more than enough to generate electricity for supplying the motors for all purposes about the power plant, and this especially so if coke-oven gas is available from works which are part of the same plant. In this case, the excess power can be used for the manufacture of many by-products, such as carborundum, calcium carbide, etc., as is being done in several European works.

"It is possible to produce a very high grade of steel by means of the electric furnace, and there is little doubt but that electric furnaces will be utilized in the near future in many plants in this country and abroad for the production of a high-grade steel. Steel is now being made in Sweden, Switzerland, France and

other European countries by electric fusion with great success, and another application for electric current in iron and steel plants worthy of consideration is that of the electromagnetic concentration of iron ores, which has been applied with greatest success in this country.

" Where the electric power generated in these plants cannot be all utilized to advantage in or about the works it is suggested that by means of suitable transmission lines the surplus power may be utilized for operating electric railways and also for lighting the streets of adjacent cities. The revenue from such a source would be a considerable amount, and in a sense would almost make the operation of the blast furnace for the production of ore an extremely small item, since the furnace itself is indeed a very efficient gas producer." **No. 398. B.**

Effect of Manganese in Low Silicon Cast Iron. H. C. Loudenbeck. Paper read before the American Foundrymen's Association, New York, June, 1905. 1,800 w. — The author reports the results of some tests made with a view of ascertaining the effect of manganese on the chill and fracture of cast iron having a low percentage of silicon, and from these he concludes as follows:

" Manganese can be used to advantage in low silicon and chilling iron in the following cases:

" In mixtures where the percentage of scrap is large and the sulphur necessarily high (this will occur in a car-wheel mixture where usually a large portion of old metal is used) the result of this increase in manganese would be lower sulphur, lower combined carbon, less chill and greater strength.

" Very often chilled plates are required having hard chilled faces and soft backs suitable for planing. Manganese added in the right proportion will reduce the tendency to mottle and make a comparatively soft graphitic back.

" In all cases where chilling irons are melted in a cupola and the sulphur is over .7 per cent the iron can be strengthened by the use of ferro-manganese or pig iron having a high percentage of manganese.

" There are some cases where the manganese should be kept low. In the manufacture of large hydraulic cylinders it is necessary to have a close mottled iron to withstand the pressure and

prevent leakage. If the manganese is too high this mottled structure is replaced by a coarse graphitic structure, which is not satisfactory for this class of work." **No. 399.**

Iron Ores Briquettes for the Blast Furnace. Henry Louis. "Cassier's Magazine," July, 1905. 6,500 w., illustrated. — The author's views regarding the briquetting of iron ores are summed up in the following words:

"It is obvious that the briquetting of iron ores has long since passed the experimental stage, and that the smelting of briquettes in the blast furnace is also a proved economic and practical success. There is no reason to doubt that this method of dealing with finely divided iron ores, whether artificially or naturally comminuted, will be further extended in the near future. By its means such comparatively low-priced material as purple ore or pyrites residues can be converted into high-class iron ores, and seeing that Great Britain imports annually about 750,000 tons of pyrites, this one item alone is of considerable importance. Furthermore, cheap methods of crushing and concentration, combined with briquetting, will make it possible to smelt with advantage many an iron ore too poor to treat directly in the blast furnace, and the future alone will show how far the mechanical elimination of impurities from iron ores can be carried profitably. Technically, the problem is solved, but its economic limits yet remain to be defined." **No. 400. B.**

Water-Cooled Ports for Open-Hearth Furnaces. "Iron Age," May 4, 1905. 1,300 w., illustrated. — The article describes a system of water-cooled ports for open-hearth furnaces installed at the Illinois Steel Company plant and at some other plants. The device is the joint invention of Geo. L. Davidson and David R. Mathias. **No. 401. B.**

Microstructure and Frictional Characteristics in Bearing Metals. Melvin Price. Paper read before the American Society of Mechanical Engineers, Scranton, Pa., June, 1905. 10,000 w., illustrated. — The author reports the results of an investigation carried out in the laboratories of Columbia University. **No. 402.**

The Transfer of Heat at High Temperatures. Frank C. Wagner. Paper read at the Scranton meeting of the American

Society of Mechanical Engineers, June, 1905. 4,000 w. — The primary object of the experiments described in this paper was to determine the time required to raise plates of iron and steel to a welding temperature in an open-hearth regenerative furnace. **No. 403.**

The Cupola System of the Michigan Stove Company. W. J. Keep. A paper read before the American Foundrymen's Association, New York, June, 1905. 2,100 w. **No. 404.**

Cast Iron. Crushing Loads and Microstructure. W. J. Keep. A paper read before the American Society of Mechanical Engineers, Scranton, Pa., June, 1905. 5,000 w., 47 photomicrographs. **No. 405.**

METALLURGICAL NOTES AND COMMENTS

Paul Louis Toussaint Héroult

Paul Louis Toussaint Héroult (see frontispiece) was born at Thury-Harcourt (Calvados, France), April 10, 1863. After attending the preparatory school attached to the School of Mines, Mr. Héroult in 1884 entered the employ of an industrial firm, before completing his engineering studies, and began at once his remarkable investigations dealing with the extraction of aluminum. In 1886 Mr. Héroult obtained a patent for his process of producing aluminum by an electrolytic method, which was destined to completely revolutionize the metallurgy of this metal, reducing its price from 100 francs in 1884 to 2.5 francs per kilogram in 1901. In 1887 Mr. Héroult obtained a patent for what may be considered as the first really industrial electric furnace. Our readers are too familiar with Mr. Héroult's recent development of the electric furnace applied to the direct extraction of iron and steel as well as to the refining of cast iron to require more than a passing notice here. As stated elsewhere in this issue Mr. Héroult is to take charge of the experiments to be conducted by the Canadian Government to ascertain the practical value of electric smelting under the conditions prevailing in that country. Mr. Héroult's results will be awaited with much interest by iron metallurgists of all countries.

Last January Mr. Héroult was awarded the Lavoisier medal by the Société d'Encouragement pour l'Industrie Nationale.

American Society for Testing Materials

The eighth annual meeting of the American Society for Testing Materials was held at Atlantic City, N. J., from June 29 to July 1, some 200 members being in attendance. The secretary reported an increase in membership of 192, bringing the total membership to 677, while the number of technical committees has been increased from 11 to 18. W. H. Bostwick and John McLeod were elected to fill vacancies in the executive committee. Re-

ports of the various committees were presented at the meetings and the following papers of special interest to our readers were read and discussed:



C. B. Dudley, President American Society for Testing Materials

"Protection of Iron and Steel Structures by Means of Paper and Paint," by Louis H. Barker.

"Some Causes of Failure of Rails in Service," by Robert Job.

"Influence of Methods of Piling Staybolt Iron on Vibratory Tests," by H. V. Wille.

"A Preliminary Report on Tests of Nickel Steel and Carbon Steel under Combined Stresses," by E. L. Hancock.

"A Comparison of Standard Methods of Testing Cast Iron," by Richard Moldenke.

"Hard Cast Iron: The Theory of One of its Causes," by Henry Souther.

"The Thermit Process in American Practice," by E. Stuetz.

"Rail Sections as Engineering Structures," by P. H. Dudley.

Three of these papers will be found reproduced in full in the present issue of *The Iron and Steel Magazine*, while the others will be printed in subsequent numbers.



Edgar Marburg, Secretary-Treasurer American Society for Testing Materials

The Thursday evening session was held jointly with the Society for the Promotion of Engineering Education, and President Dudley read an excellent address on "The Testing Engineer."

American Foundrymen's Association.

The American Foundrymen's Association held its eighth convention in New York, June 6 to 8. The usual reports of committees were presented and many papers read and discussed, among which we quote the following as of special interest to our readers:

"Notes on Some Retort Coke Melting Ratios," by C. M. Schwein, Milwaukee, Wis.

"Melting Steel with Cast Iron," by R. P. Cunningham, Holyoke, Mass.

"Notes on Pipe Foundries and Suggestions on Metal Mixers for Foundry Purposes," by J. B. Nau, New York City.

"Some Thoughts on Modern American Foundry Practice," by John C. Burns, Plainfield, N. J.

"The Effect of Manganese in Low Silicon Cast Iron," by H. C. Loudenbeck, Wilmerding, Pa.



Thos. D. West, President-elect American Foundrymen's Association

"Blowers, Piping and Cupolas at the Plant of the Michigan Stove Co.," by W. J. Keep, Detroit, Mich.

"The Use of Thermit in a Railroad Shop," by Jas. F. Webb, of Elkhart, Ind.

"Report of the Committee on Standard Methods of Determining the Constituents of Cast Iron."

"Fan Blower *v.* Positive Pressure Blower," by H. F. Field, Pittsburg, Pa.

"A Practical Foundry School," by W. C. Bruce, Cleveland, Ohio.

Some of these papers will be found abstracted in the present issue of *The Iron and Steel Magazine*, while the others will be published or reviewed in subsequent issues.

The Carnegie Steel Cross-Tie. — The Carnegie Steel Company, Pittsburg, Pa., has for some time been furnishing promi-

nent railroad companies with considerable quantities of steel cross-ties. It is believed that the near future will witness material development in the use of metal ties to replace the wooden ones. Wooden ties are steadily growing scarcer and dearer. Herewith illustrations are given of the new tie which has been brought out by the Carnegie Steel Company, together with the method of its use. Fig. 1 is a cross section of the tie, which, it will be observed, is an exaggerated form of the well-known I-beam. This section combines ample bearing surface of a proper shape for bedding and tamping, sufficient surface for seating the rail, the greatest rigidity and transverse strength for a given weight of material, and an easy means for securing the rail to

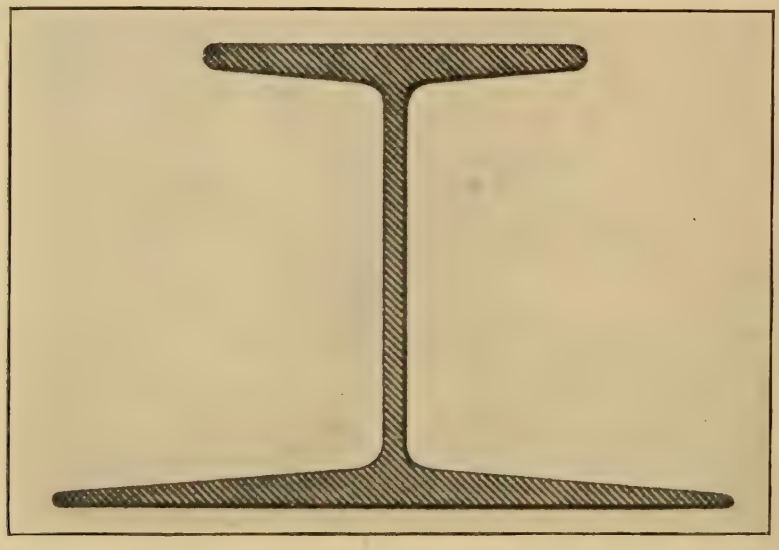


FIG. 1. Cross Section of the Carnegie Steel Cross Tie

the tie. It has a top flange $4\frac{1}{2}$ inches wide, a bottom flange 8 inches wide, a depth of $5\frac{1}{2}$ inches, is 8 feet, 6 inches in length, and weighs 19.7 pounds per foot, or a total weight of 167.4 pounds per tie, exclusive of fastenings, which weigh about 6 pounds. The rail is secured to the tie, as shown in Fig. 2, with four three-quarter-inch bolts, by means of rolled steel clips, fitting accurately on the flange of the rail. These clips have a bevel exactly the same as that of the flange of the rail and are carefully punched so that the shoulder of the clip gives proper and positive rail alignment. The necessary insulation, where automatic block signals are in use, is provided for by the use of wooden shims

between the rail and the tie, fiber bushings around the bolts and fiber washers under the nuts.

These ties have been used in sufficient quantities to demonstrate their efficiency during the past two years on lines carrying fast and heavy traffic, as follows: Duluth & Iron Range Railroad, Bessemer & Lake Erie Railroad, New York Central & Hudson River Railroad, Lake Shore & Michigan Southern Railroad.

An order has just been placed by the Bessemer & Lake Erie Railroad with the Carnegie Steel Company for ten miles of these ties, the order amounting to about 2,100 tons. This order follows a test of a half mile of the Carnegie steel tie for the past

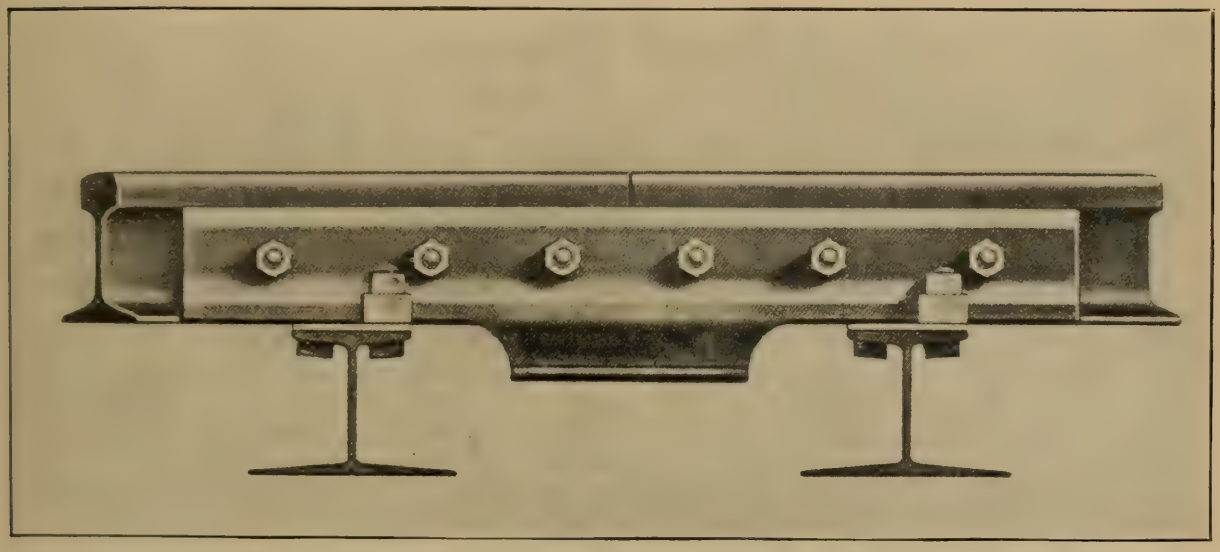


FIG. 2. The Carnegie Steel Cross-Tie as applied at a joint

six months. Arrangements are being made to have the tie used on the Pennsylvania Railroad, near Emsworth, Pa. "The Iron Age," June 22, 1905.

The Electro-Metallurgy of Iron Alloys. — Although much has been said about the practicability of using the electric furnace for the smelting of iron and the refining of steel, it has been realized that the element of cost must, at the present time, prevent such methods from entering into general competition with the older processes. At the same time there is a field in which the electric furnace can be employed where

the question of the cost of the product is secondary to its quality, and for such work the electric furnace possesses numerous advantages. In recent issues of " Stahl und Eisen " there is given an account by Herr V. Englehardt, of the progress which has been made in the practical operation of the Kjellin process for producing high-grade alloy steels in the electric furnace, and some abstract of these papers will be found of interest.

The experimental researches of Kjellin have been conducted since 1899 at the Gysinge Iron Works, situated on the Dalelf, about four hours by rail from Stockholm in Sweden. These works operated a blast-furnace forge and sulphite-cellulose works, this latter being the development of the facilities of the neighboring forest, and here in March, 1900, the first electric furnace, with a capacity for utilizing 78 kilowatts of electric energy, was put into active operation, turning out 270 kilograms of cast steel in twenty-four hours, with a consumption of about 7,000 kilowatt-hours of electric energy per metric ton of steel. This was soon improved by the production, in a second furnace, of 600 to 700 kilograms of steel in twenty-four hours, with a consumption of 2,140 kilowatt-hours per ton. In July, the cellulose works were destroyed by fire, and the energy that had been required for this portion of the establishment was diverted to the service of a third and still larger furnace, in which still more successful results have been obtained.

The Kjellin process is practically a reproduction of the crucible process of making steel by fusing the materials in such proportion as to give the required carbon content to the product without requiring any subsequent additions to the charge. The only differences are the substitution of electric methods of producing the required temperature and the arrangement by which larger quantities can be handled than is practicable with the crucible process. Further, the Kjellin furnace is an induction apparatus, there being no contact of electrodes or any external parts with the charge, and hence there is no possibility for the introduction of any impurities, either solid or gaseous, so that the purity of the product is dependent entirely upon the purity of the material with which the furnace is charged.

The furnace itself is practically a stepdown transformer, and the simplicity of its construction is marked. In an ordinary transformer the high-tension current passes through a coil of

proper fineness, wound about an iron core, while around this again is wound the coil of heavier wire in which the induced current is produced when an alternating current traverses the inner coil. In the case of the Kjellin furnace the outer coil is replaced by an annular channel, or sort of gutter, formed in the refractory material of the furnace, the wire coil and its iron core being in a central space so arranged that a free circulation of air is permitted. The charge of metal in the annular trough or gutter forms the short-circuited outer winding, so to speak, of the transformer, and the heat generated in the mass of the metal is employed to effect the fusion of the combination. It is evident that the capacity of the trough may be made sufficient to hold the charge required, and that this ring-like crucible may be kept closely covered during the entire operation, the completed run of steel being drawn off by a tap hole into a ladle and poured into molds as desired.

The latest furnace of this type differs from the earlier ones in dimensions only, the simplicity and effectiveness of design having been such as to render no radical changes or modifications necessary.

From the records of the works it appears that the output of a furnace is about 5,000 kilograms of steel in twenty-four hours, the power required being 167.1 kilowatts, or about 222 electrical horse-power, giving 4,010 kilowatt-hours per day, or 802 kilowatt-hours per metric ton of steel. Records for another day show a better result, the consumption of electrical energy being 770 kilowatt-hours per ton.

Herr Englehardt gives a very complete thermal analysis of the working of the furnace, showing that the theoretical consumption of energy should be 489 kilowatt-hours per ton of steel, so that the above performances indicate an efficiency of more than 60 per cent for the actual process.

The current at Gysinge is at present derived from water power, and under these conditions it is maintained by Kjellin that the highest grade of crucible steel can be made at a lower cost than by the crucible process. It is suggested also that such furnaces may well be operated in connection with blast furnaces, the electrical energy being obtained from the waste gases of the blast furnaces, used in gas engines, thus furnishing a method of utilizing the power in the gas in an allied line of

work instead of using it to generate electric current to supply an outside market.

The Kjellin process has also been used to work with pig and ore as well as with pig and scrap, and the results have been encouraging when a high grade of ore is employed.

It is evident that the economy of the process is dependent almost entirely upon the cost of the electrical energy, and computations for one locality cannot therefore be used for another unless the comparative cost of current is known. Data for a large furnace, to consume 1,000 h. p., are given for a daily production of 30 to 36 tons, from which it is computed that steel can be made for about 70 marks per ton, but practical operations have not yet been carried out on such a large scale. "Engineering Magazine," May, 1905.

The Metallurgist and His Work. — The man to whom this title applies has to control vast operations of a widely varied nature. So far, only Kipling has immortalized the engineer in that poetical contribution to technics, " M'Andrew's Hymn." Some day, we trust, he will render equal justice to the metallurgist, for, indeed, without the latter the civilized world would revert to barbarism. The engineer, the electrician, the physicist and the chemist may all plan, but it is eventually the metallurgist upon whom they rely. To repeat again our first president's remark, " There is hardly a necessity or convenience of life to the production of which iron has not contributed."

To our brothers in the technical professions we freely admit our indebtedness, but the *fons et origo* is the metallurgist, who enables the ideas of the engineer and the physicist to be carried into effect.

The three main arteries of modern progress — the railway, the steamship and the electric telegraph — would never have existed without the aid of metallurgy; there are still many great and complicated problems in that field to be solved. Higher speeds, increased wear and tear, the outcome of modern requirements, demand the consideration of most complex questions; but I would ask, " Have we not risen to the occasion? " Do we not guard well the lives and safety of the people? On the steel rail and on the steel ship-plate, how entirely the civilized world depends for its communications, nay, for its existence! In the

science of war the 12-inch gun hurls its projectile with a muzzle velocity of about 2,600 foot-seconds, and with the enormous energy of 42,000 foot-tons stored in it. How mighty are the powers of resistance to stress in the steel of which it is constructed! The recent development of high-speed cutting steel is revolutionizing machine-shop practice throughout the world. From the iron-manganese alloy, containing 4 per cent to 5 per cent of manganese, and but little over .40 per cent carbon, which in its cast state is so friable that it can almost be powdered between the fingers, to chromium steel having an elastic limit of 70 tons per square inch, and 100 tons or more tenacity, or to the nickel-manganese alloy, with a tenacity of 60 to 65 tons, which draws out cold in the testing machine to 60 per cent or 80 per cent of its length, is a wide range of production; and there are a thousand and one types and varieties between these limits.

It has been well said that metallurgy, like applied chemistry, appears to be comparatively simple in its practical aspect; but theoretically it is extremely complex and varied.

The only possible way to make satisfactory progress is to combine the practical with the theoretical in the training of our metallurgists. Rule-of-thumb methods no longer suffice. Much of the mystery which has surrounded our science has been swept away; and rightly, for it is only by the intelligent application of scientific principles, balanced by and co-operating with sound practical knowledge, that the metallurgist can meet the complex requirements of the day. He is neither completely chemist nor completely physicist, but he owes a debt of gratitude to both. Many are the problems submitted for his consideration. He is brought in contact with the needs and difficulties of engineers of all branches. Whilst the naval architect and the military engineer demand from him, on the one hand, armor impervious to penetration, the artillerist, on the other hand, asks for projectiles which shall, without showing crack or blemish, pierce this impenetrable armor.

In speaking of the importance of the metallurgist, it can be safely said that, except for his labors, the world would never have emerged from the darkness of the Middle Ages; if we were without iron there is hardly a single modern advance which would not be absolutely and irretrievably lost.

As our first president pointed out in his opening address,

" It is hardly possible to name a single necessity or convenience of life to the production of which iron has not contributed." This applies now with even more force than in 1869, when it was uttered. From R. A. Hadfield's Presidential Address, " Iron and Steel Institute," May, 1905, meeting.

The Position of the Steel Foundry. — The steel casting industry in the United States has had not a little attention in recent years. Manufacturers of gray iron and malleable castings have been hearing from time to time of the substitution of steel for their products, and there has been also some use of steel castings instead of forgings. However, an examination of the statistics of the industry would indicate that perhaps undue importance has been attached to the effect of the displacement of gray iron and malleable castings by steel castings. It is true that cast steel frames for locomotives are taking the place of forged frames, and that this means 5 tons of steel castings for the average locomotive. It is true, also, that draw bars are now largely specified to be steel castings instead of malleable castings, and that car bolsters and center plates and wheel centers come from the steel foundry. It is well known, moreover, that steel rolls and housings and other steel castings are increasingly in use in rolling mills. In the discussions on the inroad of steel upon gray iron these facts have been given prominence, and the deduction has been made that gray iron and malleable castings have a steadily narrowing field.

The statistics of the American Iron and Steel Association show that the production in the past five years of the various classes of steel castings has been as follows:

PRODUCTION OF STEEL CASTINGS IN THE UNITED STASES. — GROSS TONS

	1900	1901	1902	1903	1904
Acid open-hearth ...	134,847	206,681	255,475	265,469	203,915
Basic open-hearth ..	42,644	94,941	112,404	134,879	98,919
Bessemer	6,467	6,764	12,548	18,099	16,051
Crucible	3,989	3,927	4,955	5,409	4,308
Miscellaneous	4,856	5,257	5,553	6,409	7,018
Totals	192,803	317,570	390,935	430,265	330,211

It will be seen that the falling off in 1904 from the high record reached in 1903 was marked, being no less than 23 per

cent, and that the output of steel castings last year was but little more than in 1901. There are no statistics of the production of gray iron, chilled iron and malleable castings, but some comparison can be made between the two years by taking the production of foundry and malleable Bessemer iron. For 1903 the production of foundry iron in the United States was 4,409,023 gross tons, and of malleable Bessemer 473,781 tons. Last year the production of the two classes of iron amounted to 3,827,229 tons, and 263,529 tons, respectively. This indicates a decline of 16.2 per cent, but stocks of iron were less on December 31 than on January 1, 1904, so that the actual falling off in the production of gray iron and malleable castings last year as compared with 1903 was probably less than 15 per cent. The greater shrinkage in the steel castings trade was largely due, doubtless, to the failure of railroad demand last year. Another noteworthy feature of the statistics is the relatively small tonnage of Bessemer steel castings produced in the United States. So much has been said about the rapid introduction of the small Bessemer converter in steel foundries that it might be expected to have made a larger impression upon the industry. But as the small converters are employed, as a rule, on small castings calling for high heat and fluidity in the metal, tonnage does not count up rapidly. The average for 1900 and 1901 was nearly doubled in 1902 with an output of 12,548 tons, then increased about 50 per cent, to 18,099, in 1903, and fell back to 16,051 tons in 1904.

But perhaps the most striking impression that will be obtained from the figures is that of the relatively small proportion of the total of castings produced in the United States that comes from steel foundries. It is probable that not more than 6 per cent of the total of iron and steel cast in sand molds in 1904 was steel.

In recent months the steel casting industry has shown a good recovery from the stagnation that especially marked it in 1904. From the 2-cent level, touched at the worst of last year's depression, prices have advanced materially, and are now in some cases 75 to 100 per cent above low point. However, there are indications that the country has ample capacity to care for its needs in the immediate and even more remote future. "Iron Age," June 29, 1905.

Dry Air in the Blast Furnace. — It is worth notice that no ironmaster at home or abroad has hastened to adopt the Gayley system. Mr. Windsor Richards said that, on Mr. Gayley's showing, the output of a single furnace might be augmented by 25,000 tons per year, with a saving of 30,000 tons of coke. But Mr. Richards added that it remained to be proved that such economies could be realized in this country. The cooling plant is expensive, yet it seems that it would pay for itself in one or at most two years; and this being so, we might naturally expect to see the system adopted everywhere. The fact that no such adoption is going on seems to show that a good deal of incredulity still exists. We are not surprised. The manufacture of pig iron has long been a strictly scientific pursuit; and before "improvements" are accepted as worth having, they must have some firm basis of explanation to stand on. Ostensibly the cooling and drying of air for the blast furnace produces unexplained economies, and men refuse to invest capital on rule-of-thumb schemes which appear to be more or less flatly opposed to all that is believed concerning thermodynamics. The iron ore is deoxidized by the aid of a high temperature in the presence of carbon. How the process is affected by a small quantity of steam gas no one seems to be able to tell us with certainty The heat saved by the removal of a part of this steam gas is too insignificant to represent anything like a saving of 20 per cent or so of fuel. Possibly the result is due to a number of causes, all working together. For ourselves, until something much more conclusive has been advanced than anything yet brought forward we shall continue to hold that the major portion of the saving is due to an increase in the density of the blast. If this is not true, then we must unlearn what has been taught concerning the cost of dissociation, or take it for granted that the presence of small volumes of free hydrogen in a blast-furnace hearth is inimical to economy. "The Engineer," June 2, 1905.

Electric Smelting of Iron Ore. — The smelting of iron ore by electricity is to have a practical working test in Canada. The Dominion government has appropriated $15,000 for the purposes of the test, and a building and free power will be furnished for a limited period at the Sault Ste. Marie works. The test will be under the special charge of M. Héroult, the French en-

gineer, who has a wide reputation for his operations and experiments in electrical smelting in France. It is understood also that some experiments will be made with nickel ores from Sudbury. Should the experiments result successfully, the Canadian government will probably spend a larger sum in erecting a plant at some point in the vicinity of the iron ranges of western Ontario. " Engineering and Mining Journal," June 15, 1905.

Success of Open-Hearth Rails. — The Tennessee Coal, Iron & R. R. Co. has for some time had sufficient tonnage on its books to insure operation throughout the year, and some orders for 1906 were booked by that company several months ago. The success of its open-hearth rail is being emphasized by the fact that the company has very recently taken orders for a considerable additional tonnage for 1906 delivery. The Youngstown mill is now operating on billets and sheet bars and later rails and billets will be rolled. The consumption of steel will, therefore, be greatly increased as well as pig iron. The idle Bessemer plant at New Castle is scheduled to resume shortly after the first of next month. " Iron Trade Review," June 22, 1905.

Distinctions for a Distinguished Metallurgist. — The honorary degree of LL.D. was recently conferred upon Henry Marion Howe both by Harvard University and by Lafayette College. President Eliot's words in conferring the degree were the following:

" Henry Marion Howe, a Boston Latin School boy, Harvard Bachelor of Arts and Institute of Technology Bachelor of Science, an author on copper, iron and steel, distinguished for scientific imagination and a good English style, professor of metallurgy at Columbia University, consulting metallurgist, honored by the profession in England, France, Germany, Russia and his native land."

Metallographic Gems. — Martensite is described as follows, in one of our technical contemporaries:

" The ingredient ' martensite ' of steel, though detected and identified by the microscope, has never been isolated. It seems to be a specialized interlacing of ferrite and cementite."

The same journal also enlightens us concerning the nature of the eutectic alloy in steel:

" In the case of steel, the assumed eutectic is cementite, Fe_3C (containing about 6.7 per cent of carbon)."

The Technical Press. — I take this opportunity of expressing our great indebtedness to the technical press for the wonderful work they do in keeping us supplied with the most recent information.

We often wonder at the marvels of daily journalism, but to me they do not seem to compare with the work done by the technical press, where the matter must be correct and exact. The daily press, however essential to our well-being, does work of a more or less ephemeral nature; that of technical papers is of a lasting description.

In closing my remarks on this subject permit me to tender to the technical press and its members my own personal indebtedness — which must be shared by many thousands of my fellow-workers — for the great services they are continuously rendering to us. I frankly confess that to the technical press I largely owe such progress as I have been able to make in acquiring information. Speaking *ex cathedra* one can take an opportunity that but rarely comes of expressing sentiments on this point, which, in my own case, are very deeply felt. All honor to the British, American and Continental technical press for the great work they do in helping on the cause of progress! From R. A. Hadfield's Presidential Address, Iron and Steel Institute, May, 1905.

Importance of Research and Invention.— In progressive manufacture, the complexity of which increases year by year, there is, in addition to the many ordinary difficulties met with, that of how to solve new problems which constantly present themselves. This can be done only by research, which should form an actual part of industrial operations, and demands almost as much attention as is devoted to the manufacturing side.

As one who has carried out many researches in metallurgy, and has also benefited by the scientific investigation of others, not only in this country but elsewhere, it would be an omission on my part to neglect to make reference to the practical importance of research. It is more than ever necessary not to rest satisfied with the knowledge of to-day, nor to think that this will satisfy the needs of to-morrow. Rapid and great changes are constantly occurring in metallurgy as in other branches of scientific knowledge.

Closely allied to research, though naturally of a somewhat different order, is invention. The Hon. Charles A. Parsons, in his presidential address to the Engineering Section of the British Association at the meeting in Cambridge last year, said that he considered the general encouragement of invention would be one of the greatest steps in the advancement of the human race that would take place this century. No doubt he was right. Professor Perry recently pointed out that the energy in one ton of coal was equal to the work of 40,000 laborers working ten hours a day. Yet to-day our best steam-engines only utilize one tenth of this energy. What an avenue here for research and invention! Prof. R. H. Smith has also pointed out, in a commentary regarding this question, that it is upon invention that the progress, almost the civilization, of mankind depends. He also calls attention to the fact that high scientific training is not necessarily productive of inventors. Too much scholastic training is, in some minds, apt to take away originality, and to inculcate dogmatism rather than progress. From R. A. Hadfield's Presidential Address, Iron and Steel Institute, May, 1905.

REVIEW OF THE IRON AND STEEL MARKET

A material change in the complexion of the iron and steel market has occurred since last report. A month ago there was general dullness, pig-iron prices were declining and prices of some finished steel products were weakening. The rail trade alone was showing an improvement. Subsequent developments have all been favorable. A large tonnage of southern pig iron has been sold and a moderate tonnage of northern iron. Prices of southern iron have advanced, while prices of northern iron have hardened. There has been further good buying of rails, so that all the available mills are operating, with tonnage booked until almost the close of the year. In the finished steel lines which were weakest, merchant pipe, sheets, tin plate and wire products, there has been a little increase in buying, while stocks have been greatly reduced and reports are quite encouraging as to prospects of good business in August. In the lines which have been steadily active this year, structural shapes and plates, the pressure has now reached an acute stage, the large mills being unable to offer any deliveries at all on new business or even on new specifications against old contracts, within from three to six months, while stocks have been so depleted that some smaller mills, which can make earlier shipments, are easily securing premiums over the regular prices.

It is quite unusual for the iron trade to show improvement during July, and the augury for fall business is extremely favorable. General business conditions are very good, crop prospects are excellent, and there is hardly a cloud on the horizon. The iron trade looks confidently for good business during the second half of this year, and for better business next year than this.

Pig Iron. — Sales of southern iron during July aggregated probably over 100,000 tons, or more than the current make. There was very little buying until the open market had receded to $11.25, Birmingham, for No. 2 foundry, whereupon, by making inside prices the southern furnaces tempted a large business, the largest buyer being the cast-iron pipe consolidation, which

took 25,000 tons or more. The prices at which this business went are not exactly ascertainable, but are supposed to have been from $10.50 to $11.00. The market then advanced sharply, most large producers advancing to $11.50 and in many cases asking $12.00 for fourth quarter, leaving but little iron to be had at $11.25 and nothing at lower figures. Of northern iron there have been only moderate sales, but the situation is working out in the direction of large buyers coming into the market shortly. The lowest prices now named cover only a limited tonnage, for early shipment, and as soon as this iron is taken the higher prices already named by some furnaces are likely to prevail. Sales of No. 2 foundry have been made at $14.00, f. o. b. central western furnace, and possibly lower. On malleable Bessemer, $14.00 at furnace has been shaded materially, and by a small amount on standard Bessemer. We quote prices as follows, the lower figures, being, as noted, on comparatively small offerings which are likely to be absorbed shortly: F. o. b. valley furnace: Bessemer, $14.25 to $14.50; basic, $14.00 to $14.25; No. 2 foundry, $14.00 to $14.25; gray forge, $13.50 to $13.75. Delivered Pittsburg: Bessemer, $15.10 to $15.35; basic, $14.85 to $15.10; No. 2 foundry, $14.85 to $15.30; gray forge, $14.35 to $14.60. F. o. b. Birmingham: No. 2 foundry, $11.25 to $12.00; gray forge, $10.25 to $11.00. Delivered Philadelphia; No. 2 X foundry, $16.25 to $16.50; standard gray forge, $14.50 to $14.75. Delivered Chicago: northern No. 2 foundry, $16.25 to $16.50; malleable Bessemer, $16.25 to $16.50. Freight: Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65.

Steel. — Buyers' ideas have been that they should be able to buy steel for third quarter at prices considerably lower than those which prevailed for deliveries in second quarter, but have found that very little steel could be picked up at such figures, the leading interest holding to higher prices and appearing to have the market well in hand. We would, therefore, quote Bessemer 4 x 4 and larger billets at $23.00; sheet bars, long lengths, $24.50; sheet bars, cut, $25.00, — all f. o. b. Pittsburg, for third quarter delivery.

Shapes. — There is still more pressure on the structural mills, the leading interests having specifications which will keep them busy for from four to six months. As they are behind on these, they cannot take new business for earlier shipment, and such

business is going to some of the smaller eastern mills, generally at premiums. Regular mill prices were reaffirmed on July 19 at 1.60 cents for beams and channels, 3 to 15 inch inclusive, angles 2 x 3 to 6 x 6 inclusive, and zees.

Plates. — Conditions are much the same as in shapes. There have been good inquiries for steel cars lately, and another buying movement may be inaugurated. Prices were reaffirmed on July 19 at 1.50 cents for plates 14 inches wide and under, and 1.60 cents for plates over 14 and not over 100 inches wide, for tank quality, quarter-inch and heavier, with the usual advances for other grades and sizes.

Merchant Bars. — Specifications on steel bars have improved, there is less shading by overloaded jobbers, and some small business is being placed with the mills at full prices, while some large consumers have begun considering the question of material for next year. In general, the market can be quoted at the regular price of 1.50 cents, half extras, f. o. b. Pittsburg, carload and larger lots. The iron-bar market is quiet and we continue to quote 1.55 cents to 1.60, Pittsburg. The Chicago market, after taking a dip to 1.45 cents, has returned to our last quotation of 1.50 cents to 1.55, there being difficulty in doing the lower figure.

Sheets. — Wage matters with the Amalgamated Association, which controls about one fourth of the leading interest's sheet mills and over half of the independents, have been satisfactorily adjusted for the year beginning July 1, on the basis of former rates, with the output limit entirely abolished. Most of the union mills are still closed, and some of the non-union mills. Demand continues fairly good and stocks are becoming exhausted, so that mill business should improve during August. We quote 2.35 to 2.40 cents on black and 3.40 to 3.45 cents on galvanized, No. 28 gauge, for ordinary carloads. On a desirable order about 5 cents a hundred less can be done.

Scrap. — The decline in scrap appears to be over, the market having shown a slight hardening tendency. Small lots of heavy melting stock can be picked up occasionally at $14.00, delivered Pittsburg, but any fair-sized quantity would bring $14.25 to $14.50. Other prices are approximately as follows: Sheet scrap, $12.50 to $13.00; old car wheels, $14.50 to $15.00; cast borings, $8.00 to $8.25 — all gross tons, delivered Pittsburg.

STATISTICS

Steel Production in Canada.* — The following table gives the production of all kinds of steel ingots and castings in Canada from 1894 to 1904, in gross tons:

Years	Gross Tons	Years	Gross Tons	Years	Gross Tons
1894 . . .	25,685	1898 . . .	21,540	1902 . . .	182,037
1895 . . .	17,000	1899 . . .	22,000	1903 . . .	181,514
1896 . . .	16,000	1900 . . .	23,577	1904 . . .	148,784
1897 . . .	18,400	1901 . . .	26,084		

The following table gives the production of all kinds of iron and steel rolled into finished forms in Canada from 1895 to 1904:

Years	Gross Tons	Years	Gross Tons	Years	Gross Tons
1895 . . .	66,402	1899 . . .	110,642	1903 . . .	129,516
1896 . . .	75,043	1900 . . .	100,690	1904 . . .	180,038
1897 . . .	77,021	1901 . . .	112,007		
1898 . . .	90,303	1902 . . .	161,485		

The production of Bessemer and open-hearth steel rails in 1904 amounted to 36,216 gross tons, against 1,243 tons in 1903; structural shapes, 447 tons, against 1,983 tons in 1903; cut nails made by rolling mills and steel works having cut-nail factories connected with their plants, 99,000 kegs of 100 pounds, against 118,686 kegs in 1903; plates and sheets, 3,102 tons, against 2,450 tons in 1903; all other finished rolled products, excluding muck and scrap bars, blooms, billets, sheet bars and other unfinished forms, 135,243 tons, against 118,541 tons in 1903. The total quantity of all kinds of steel and iron rolled into finished forms in Canada in 1904 amounted to 180,038 tons, against

* "The Bulletin," American Iron and Steel Association, June 1, 1905.

129,516 tons in 1903. Of the 180,038 tons of finished iron and steel reported for 1904, about 126,850 tons were steel and 53,188 tons were iron.

On December 31, 1904, there were 18 completed rolling mills and steel works in Canada. In addition, 3 plants were being built, and 2 plants were projected. Of the completed plants, 2 were equipped for the manufacture of steel castings only, 5 for the manufacture of Bessemer or open-hearth steel ingots and rolled products, and 11 for the manufacture of rolled products only. Of the building plants, one was being equipped for the manufacture of steel castings by a special process, one for the manufacture of open-hearth steel ingots only, and one for the manufacture of merchant bar iron, railway spikes, etc. One of the projected plants is to be equipped for the manufacture of skelp and bar iron and the other for the manufacture of wire rods.

Of the 18 completed rolling mills and steel works in Canada on December 31, 1904, 3 were located in Nova Scotia, 5 in Quebec, 9 in Ontario, and 1 in New Brunswick. The building plants are in Nova Scotia, Ontario and Manitoba, and the projected plants are in Ontario.

We are officially advised that the production of iron ore in Canada in 1904 amounted to 312,286 gross tons, against 235,977 tons in 1903, and that the production of coal in Canada in 1904 amounted to 6,705,232 gross tons, against 6,824,999 tons in 1903. The figures for 1904 are subject to revision, but are substantially correct.

Iron and Steel Imports and Exports.* — During the first ten months of the present fiscal year, which ends on June 30, this country imported iron and steel and manufactures of iron and steel of the value of $18,488,000, against $23,077,552 in the corresponding months of the preceding fiscal year, and it exported iron and steel and manufactures thereof of the value of $110,788,570, against $89,107,854 in the corresponding months of the preceding fiscal year. Of the imports in the last ten months, ending with April, we note 81,028 tons of pig iron and 8,496 tons of iron and steel rails, against 181,889 and 37,632 tons respectively in the ten months of the fiscal year 1904, and

* "The Bulletin," American Iron and Steel Association, June 1, 1905.

of the exports in the last ten months we note 42,534 tons of pig iron and 372,380 tons of steel rails, against 29,945 and 68,405 tons, respectively, in the ten months of the fiscal year 1904.

German Steel Production.* — The corrected report of the German Iron and Steel Union gives the production of steel in Germany for the full year as below, in metric tons:

	Acid	Basic	Total
Converter ingots	423,742	5,525,429	5,949,171
Open-hearth ingots	130,546	2,697,760	2,828,306
Direct castings	56,409	96,405	152,814
Total	610,697	8,319,594	8,930,291
Total, 1903	613,399	8,188,116	8,801,515

The total production last year showed an increase of 128,776, or 1.5 per cent, over the previous year. It will be noted that 93.2 per cent of the total was basic steel, and that 55.4 per cent was made in the converter.

* "Engineering and Mining Journal," June 22, 1905.

RECENT PUBLICATIONS

Statistics of the American and Foreign Iron Trades for 1904. 136 6 × 9-in. pages; paper covers. The American Iron and Steel Association. Philadelphia. 1905. Price, $5.00. — This is Mr. Swank's thirty-third annual report, and in degree of exhaustiveness and general excellence it even excels the high standard of his previous reports. It was presented to the members June 10, and the collection of such a vast amount of information at so early a date is in itself a feat deserving of high commendation. The American Iron and Steel Industry is certainly fortunate to have had for so many years the services of so eminent and capable a statistician.

"This report embraces all the leading features of previous reports and also many new features. The statistics of production of iron and steel are full and complete. Tables are given which show our annual imports and exports of iron and steel, tinplates, iron ore, etc. Details are given of the shipments of iron ore from the Lake Superior and other mines, the imports of Cuban iron ore, the prices of Lake Superior iron ore, the shipments and prices of Connellsville coke, the imports and exports of coal and coke, the tonnage of steel vessels built in 1903 and 1904, immigration in 1904 and previous years, etc. Our price tables must especially commend themselves to all who are connected with the iron trade. So also must the tables relating to our production of steel, which give in detail the annual growth in recent years of every kind of steel, including all kinds of steel castings. Our statistics of rail production in 1904 are given in more than usual detail. There are other new features. Tables are given which show the production of leading iron and steel products, iron ore, etc., by the United States Steel Corporation and by independent companies in 1902, 1903 and 1904. Canadian iron and steel statistics are full and complete. Detailed statistics of the iron and steel industries of Great Britain, Germany, France and Belgium in 1903 and 1904 are also given.

The report closes with statistical tables of the world's production of iron and steel and iron ore and coal. The Necrological Record is continued.

"Following the report proper for 1904, there will be found a statistical abstract of all trustworthy statistics, mainly of our own collection, relating to every branch of the iron trade and going as far back in each instance as such statistics are available. The large number of tables we give in this abstract and their comprehensive character combine to make this feature of the present report a most valuable contribution to the history of the American iron trade and to national and international economic literature. Tables showing the prices of Bessemer rails in this country and in Great Britain for a long series of years and also showing the miles of railroad in operation in the United States since 1830 and the displacement of iron rails by steel rails since 1880, will be found valuable for reference by railroad men."

Constructional Steel Work, by A. W. Farnsworth. 248 6 × 9-in. pages; over 100 illustrations. Charles Griffin & Co. London. 1905. Price, 10*s.* 6*d.* — This book consists of "Notes on the Practical Aspect and the Principles of Design, together with an Account of the Present Methods and Tools of Manufacture." The author takes the stand that "there are in this country [England] thousands of civil and mechanical engineers, architects and surveyors who find they have, in increasingly numerous cases, to design and superintend erections involving in some form or other the employment of mild steel work, and that it has become imperative that every designer should know something about it. The present work is an effort to afford to designers generally an indication of what they should seek to embody in their creation; it is hoped that it may be also a handbook for those practically engaged in the trade." Part I deals with practical designing and is subdivided into eleven chapters, while Part II is devoted to practical shop work and contains nine chapters.

When referring to purely metallurgical questions, the author is evidently not upon his own ground. On page 17 he divides the processes employed in England for the manufacture of constructional steel into "(1) the basic, (2) the Siemens open-hearth and (3) the Siemens-Martin open-hearth acid processes."

It must be presumed that he means (1) basic open-hearth process, (2) acid (?) open-hearth processes using pig and ore, and (3) acid open-hearth process using pig and scrap. A little later, however, he refers to the second process as "open-hearth basic," adding that "through recent discoveries, it has not yet taken unto itself a definite name." What the author means by this will not, we think, be readily understood. On page 24 he gives the following figures as representing the allowable limits of foreign elements in mild steels "sanctioned by the modern metallurgical practice": Carbon .02 to .06 per cent, manganese .40 to .90 per cent, silica (meaning silicon) .00 to .05 per cent, sulphur .00 to .04 per cent and phosphorus .02 to .10 per cent. It would be interesting to know how much mild steel is being manufactured containing .02 per cent carbon, or indeed .06 per cent, and if this represents the upper limit, few mills, we think, would care to furnish it. The lower limit for silica (!) is surely low enough as well as the upper limit, and the same may be said of sulphur. In the case of phosphorus and manganese the author gives more rational figures.

Steam and Steam Engines, including Turbines and Boilers, by Andrew Jamieson. Fourteenth edition. 780 $4\frac{1}{2} \times 7\frac{1}{2}$-in. pages; numerous illustrations. Charles Griffin & Co. London. 1904. Price, 10*s.* 6*d.* The fact that this book has reached its fourteenth edition is conclusive evidence of its value and popularity. In this recent edition the author has added two lectures dealing with steam turbines and bringing that important subject up to date. Pyrometry and calorimetry are also treated at greater length than in previous editions, while increased space is devoted to thermodynamics and to wet, dry and superheated steam. The subject is treated in the form of lectures and each lecture is followed by a series of questions, there being 886 questions in the book. While it is primarily written for students, it is also a reference book of great value.

Gas Producers, by W. A. Toakey. 137 $4\frac{1}{2} \times 6$-in. pages; illustrated. Percival Marshall & Co. London. 1905. Price, 1*s.* — The increased use of the gas engine has brought gas producers to the front as never before. New producers are

almost daily described in the technical press and many articles have appeared lately descriptive of producer gas and its generation. The little book we have before us is, therefore, a timely one. It should prove of service to many because of its brief and clear treatment of the subject. The following titles of the chapters will show the ground covered: Producer Gas: Method of Generation, Composition and Qualities; The Cost of Producer Gas; Gas from Bituminous Coal: the Mond Principle; Gas from Non-Bituminous Coal: the Dawson Principle; Gas from Waste Wood, etc.: the Riche Principle; Gas from Iron Bituminous Coal: the Suction Principle; Hints for Erectors and Attendants; General Remarks; Suction Gas Plants: illustrated description of the designs offered by the leading makers.

Testing of Electro-Magnetic Machinery and Other Apparatus. Volume I. Direct Currents, by Bernard Victor Swenson and Budd Frankenfield. 420 $4\frac{1}{2} \times 8\frac{1}{2}$-in. pages; illustrated. The Macmillan Company. New York. 1904. Price, $3.50. — The authors in their preface state that this book is intended for use as a college textbook and also as a work of reference for the engineer. The field covered by the present volume is that of direct current electromagnetic machinery and apparatus, and is almost exclusively confined to dynamo-electric machinery. The second volume (which is in course of preparation) will deal with alternating current machinery and apparatus. In the present volume ninety-six experiments are described, each one being self-contained. The authors have undoubtedly bestowed a large amount of work upon this book and the indications are that the subject has been treated with great care and much authority.

Fire Assaying Notes, by F. P. Dunnington, School of Analytical Chemistry, University of Virginia. 18 6 × 9-in. pages. Eschenbach Printing Company. Easton, Pa., 1905. — This pamphlet consists of some lecture notes in which the elements of fire assaying are briefly presented.

Automobiles : Vapeur, Pétrole, Electricité, by H. Rodier. 175 9 × $12\frac{1}{2}$-in. pages; illustrated. Paris. 1905. Price, $4.25. — The automobile being essentially a machine of French origin

and having attained its highest perfection in France, it is fitting that the first exhaustive treatise on that subject should be written by a French expert. This book should be of great value to the constructor of automobiles. It is well printed on excellent paper and well illustrated.

German Technical Words and Phrases, by C. A. Thim and W. Von Knoblauch. 214 3 × 5½-in pages. F. Marlborough & Co. London. 1904. Price, cloth, 2*s*. 6*d*.; leather, 3*s*. 6*d*. — This little book is an English-German and German-English dictionary of technical and business terms and phrases used in commerce, arts, sciences, professions and trades.

PATENTS

UNITED STATES

791,170. Manufacture of Steel. — James Vernon, Newton Stewart, Scotland.

791,189. Manufacture of Manganese-Steel Rails or Shapes. — Robert A. Hadfield, Sheffield, England.

791,193. Machine for Straightening Tubes, Shafts, Bars or the Like. — Otto Heer, Düsseldorf, Germany.

791,461. Gas-Producer Apparatus. — Carleton Ellis, New York, N. Y.

791,494. Apparatus for Magnetic Separation. — Clarence Q. Payne, Stamford, Conn., assignor to the International Separator Company.

791,833. Roller-Mill. — Simon Snyder, Muncy, Pa., assignor to Sprout, Waldron & Co., Muncy, Pa.

791,928. Process of Treating Ferruginous Ore for the Manufacture of Iron and Steel Therefrom. — Montague Moore, Melbourne, and Thomas J. Heskett, Brunswick, Victoria, Australia.

791,940. Feeding Device for Slabs, Billets, Etc. — Casimir von Philip, Bethlehem, Pa., assignor to Bethlehem Steel Company, South Bethlehem, Pa.

791,958. Automatic Blast-Temperature-Regulating Valve. — Samuel W. Vaughen, Lorain, Ohio, and John W. Cabot, Johnstown, Pa.

792,047. Apparatus for Changing Blast-Furnace Bells. — Walter Kennedy, Allegheny, Pa.

792,179. Tuyere Iron. — Charles O. Swenson, Minneapolis, Minn.

792,231. Art of Cross-Rolling Tubular Bodies or Blanks in a Heated State. — John H. Nicholson, Pittsburg, Pa., assignor to National Tube Company, New York, N. Y.

792,440. Apparatus for Treating Ferruginous Ore for the Manufacture of Iron and Steel Therefrom. — Montague Moore, Melbourne, and Thomas J. Heskett, Brunswick, Victoria, Australia.

792,591. Metal-Working Machine. — James Hartness, Springfield, Vt.

792,619. Portable Furnace for Melting Steel or Other Metals. — Louis Rousseau, Argenteuil, France.

792,630. Ingot Stripper. — Clarence L. Taylor, Alliance, Ohio, assignor to the Morgan Engineering Company, Alliance, Ohio.

792,642. Melting Furnace. — William E. Williams, Chicago, Ill.

792,681. Furnace-Charging Box. — Clarence L. Taylor, Alliance, Ohio, assignor to the Morgan Engineering Company, Alliance, Ohio.

792,735. Furnace-Filling Apparatus. — John W. Seaver, Cleveland, Ohio, assignor to the Wellman-Seaver-Morgan Company, Cleveland, Ohio.

792,914. Method of Making Open-Hearth Steel. — Niven McConnell, Pittsburg, Pa.

792,992. Mold for Producing Tuyere-Molds. — Samuel A. Kelly, Pittsburg, Pa.

793,027. Indicating Attachment for Rolling-Mills. — Harry H. Burton, Southford, and James L. Burton, New Britain, Conn.; said James L. Gurton assignor to said Harry H. Burton.

GREAT BRITAIN

12,785 of 1904. Gas Smelting of Iron Ores. — E. Fleischer, Dresden, Germany. Smelting iron ores in inclined revolving tubular furnaces by means of water gas.

16,412 of 1904. Case-Hardening Steel. — Cyanide Gesellschaft, Berlin, Germany. Case-hardening iron and steel by packing with organic refuse containing a large proportion of nitrogen and heating to a high temperature.

9,202 of 1904. Smelting Iron. — R. M. Daelen, Düsseldorf, Germany. Smelting fine ores by briquetting mixtures of the ores and finely divided carbon, and after reduction charging them into a molten bath of iron to prevent reoxidization of the spongy iron formed.

27,839 of 1904. Utilizing Cupola Gases. — A. Bayot, Marly, France. Arrangement of pipes so as to catch the gases such as carbon monoxide and carbohydrates given off from foundry cupolas and utilizing them for heating the cupolas.

9,836 of 1904. Coating Iron. — A. Levy, Paris, France. Forming permanent protective coverings for iron by first coating with zinc and afterward with tin, lead or copper.

12,817 of 1904. Tempering Steel. — S. N. Brayshaw, Manchester. Tempering high-speed tool steel, by first heating in furnace, then quenching in a bath kept at about 800° C. and afterward quenching in water.

16,214 of 1904. Removing Phosphorus from Iron Ore. — W. Simpkin and J. B. Ballantine, London. Removing phosphorus from finely ground iron ores by leaching out with dilute acid solutions.

16,276 of 1904. Steel Making. — W. Kaufman, Vienna, and A. Bauvier, Grenoble, France. Improved method of introducing carbide of silicon into steel, so that it shall not be decomposed.



R. W. RAYMOND

SEE PAGE 250

The Iron and Steel Magazine

". . . . . Je veux au mond publier
d'une plume de fer sur un papier d'acier."

Vol. X September, 1905 No. 3

DESCRIPTIVE METALLURGY OF IRON AND STEEL *

By SAMUEL GROVES

Introductory

IN the primitive ages, when our ancestors dwelt in caves, they hunted the buffalo and the bear with bow and arrow and spear, tipped with *sharpened* flints and stones. It was this unique faculty of being able to *invent and form* tools and weapons of defense that "gave man dominion over the fowls of the air, the fish of the sea and everything that creepeth on the face of the earth." Moreover, this capacity to give new shape and form to existing materials makes an absolute line of demarkation between man and the lower animals. Monkeys will throw down cocoanuts from the trees, then pick up a stone and crack the shells; but they always take something ready to their hand — never make a hammer, hatchet or knife. Elephants tear down branches from the forest trees to drive away the tormenting flies, or to protect them from the burning rays of the tropical sun; but who ever heard of an elephant making an umbrella? There is not an authenticated instance in the history of the world of an animal lower than man inventing and making a tool or implement to aid his natural powers. By instinct — "a propensity existing prior to experience and independent of instruction" — the beaver builds his dam, the bee his honeycomb,

* "The Canadian Engineer," July, 1905.

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and the robin his nest, just as they did at the earliest dawn of civilization. The cave, tent, cabin, cottage, house and palace indicate the progress made by the human race. By man's unique power of *invention* the desert has been made to blossom as the rose.

The earliest records of prehistoric times show Palæolithic man dwelling in hillside caverns, supplementing his natural powers by making stone arrowheads and spear points to protect

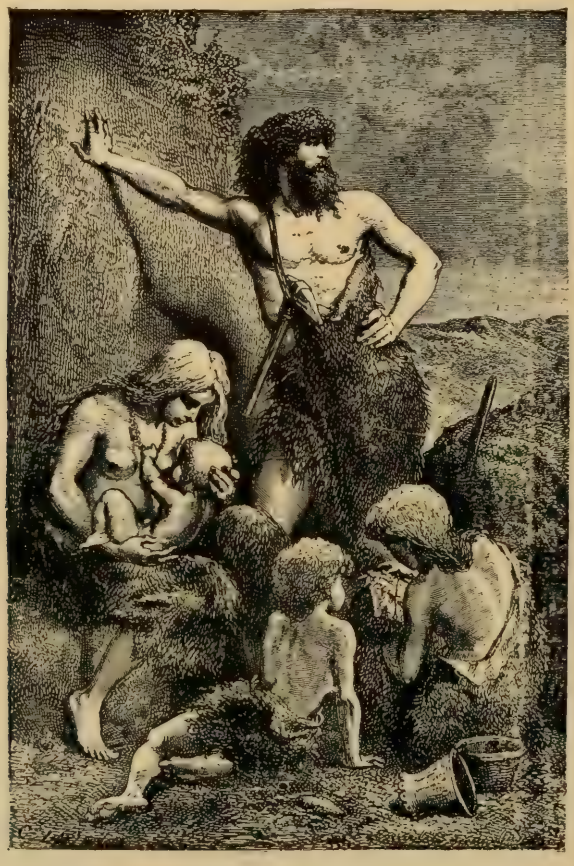


FIG. 1. A Family of the Stone Age

him from the great carnivora, or to kill wild deer for food, and shaping stone hatchets, knives and hammers for cutting up the flesh and breaking the bones. Hence this first period of man's existence has been called the

STONE AGE

Then came the discovery of copper, which was hammered into ornaments and various articles of domestic use, but was too

soft for fine-edged tools and weapons of defense. It was found, however, that by mixing the ores of oxidized copper and tin together, and melting them over a hot charcoal fire, a new metallic alloy resulted, which could be poured as a liquid into molds, making castings of all shapes and sizes, having any degree of hardness; in fact, a mixture of two parts copper and one of tin makes an alloy so hard that it cannot be cut by ordinary tool steel. It was further discovered that if the bronze was made red hot, then suddenly plunged into cold water, it becomes comparatively soft and ductile, and could be hammered into any shape, but if made red hot again, and allowed to cool *slowly*,



FIG. 2. A Founder's Workshop during the Bronze Period

would once more regain its original hardness. The native workers of bronze in India still take advantage of this diverse process, for it is the very way in which they make their cymbals and tom-toms to-day.

We thus see that in bronze, Neolithic man discovered a metallic composition admirably adapted to his nascent industrial skill, for without much trouble he could pour it as a liquid into molds having the form of hatchets, poinards, swords, agricultural implements and mechanical appliances of all kinds.

In this way began the art of founding in metals. At what precise date and in which part of the globe this simple but im-

portant invention was made is enveloped in mystery. The earliest written record is found in Genesis 4: 22, where Tubal-cain is described as "*an instructor of every artificer in brass and iron*," while tradition declares that bronze was first introduced into Central Europe by Phœnician traders about 1500 B.C.

This epoch, or second period in the story of mankind, is known as the

Bronze Age

But although bronze was a great advance over stone as a means of aiding the natural powers of primeval man, yet, as organized communities took the place of the patriarchal family and tribe, and the wants of the social organism became necessarily more varied and complex, it was found that copper and tin, and the bronze alloy made therefrom, were not elastic and hard enough, and the supply of their ores not plentiful enough, to meet the increasing demands of the newly formed societies. And since "Necessity is the mother of invention," and the art of metallurgy had made great progress during this epoch, as the unearthed prehistoric relics of the period show, it is not surprising that Tubal-cain, or some other skillful founder in "brass," tried the experiment of smelting in a hot charcoal furnace the red oxides of iron which they found in abundance cropping out of the hillsides, and succeeded in easily producing lumps of metal, unalloyed, which could be hammered into knives, hatchets, scythes, plowshares, etc., for domestic use or cultivation of their lands in the "piping times of peace," and swords, spears, armor, etc., for use in the chase, or stirring times of war and conquest.

With the advent of iron began a new era in the social evolution of mankind, known as the

Iron Age

As in the case of bronze, so in the case of iron, the exact time and place of the discovery is unknown; but archæological remains, gold trinkets, bronze coins, ivory ornaments, iron swords, scythes, etc., together with rudely built smelting furnaces, found in the hillsides and prehistoric tombs of Hallstadt, Austria, and Jura Mountains of Switzerland, clearly prove that 2000 B.C. a Gallic race inhabited these regions of Central Europe,

who, by taking advantage of the discovery of iron, and trading their manufactures with the Phœnicians, enjoyed material comforts and luxuries and developed skill and taste in the cultivation of the arts of life, far in advance of the rugged nomadic tribes and people by whom they were surrounded, bearing out the famous dictum of Thenard, the chemist, that we may judge of the state of civilization of any nation by the degree of perfection at which it has arrived in the workmanship of iron.

The method by which these men of the early Iron Age extracted metallic iron from mineral ore is graphically illustrated in Fig. 3. This picture was drawn from a model in relief,



FIG. 3. Primitive Furnace for Smelting Iron

prepared in 1866 by a learned Swiss engineer, M. Quiquerez, and designed from many specimens found in Hallstadt, Austria, and in the Bernese Jura. The furnace consisted of a cavity in the hillside, covered in with a concave wall about nine feet high, plastered with fireclay, and surmounted with a conical chimney. Steps made of rough stone were arranged on each side of the mound to enable the workman to climb on top in order to charge with ore and fuel. On the right-hand side is a heap of charcoal for fuel, while on the left is a store of ironstone, enclosed in a pen formed of long, wooden logs. In the foreground is a heap of scoria, hammer slag and scale, dropped as débris in the pro-

cess of hammering the crude metal. A workman is pulling a cake of iron out of the ashes; another is hammering on the anvil a piece of spongy iron, just taken from the furnace. In all these researches no trace was found of the use of bellows, natural draught only being used at this period; hence there is no proof that *founding in iron* existed in prehistoric times. To fuse iron ore and reduce it to a liquid condition requires a temperature of some 2200° F., and this high temperature is not attainable in the natural draught furnace described. In these ancient furnaces the iron in the mineral ore was only reduced to a red-hot spongy state, and dropped down among the ashes in the form of pasty lumps of malleable iron, weighing from twelve to sixteen pounds, which were worked on the anvil by artisans skilled in the craft of Tubal-cain.

So far we have followed the footprints of primitive man up through the mists of antiquity, guided only by the evidence furnished in roughly chipped flints and stones, cunningly worked bronze tools and ornaments, rudely formed iron weapons, implements, etc., found in deep caverns, embedded in solidified mud or under alluvial deposits of past geological ages.

It is not until 1050 B.C. that we cross the threshold of history, and enter the domain of scientific fact. The first historic record is found in Solomon's famous message to Hiram, king of Tyre (2 Chron. 2: 7), where he requests the Phœnician monarch to assist him in building the Temple of Jerusalem, in the golden age of Judea. Said he:

"Send me now therefore a man cunning to work in gold, and in silver, and in brass, and iron."

The next instance is found in Homer's "Iliad," written about 850 B.C.:

"And the Greeks bought wine for shining steel, and some for sounding brass." — (*Book VII.*)

And where the Trojan captive spy, Dolon, tries to bribe the Greeks:

". . . He, weeping, offered a wealthy ransom for his life, and told them he had brass, much gold, and iron, that fit for many labors was, from which rich heaps his father would a wondrous portion give." — (*Book X.*)

From this time forward the material progress and civilization of the human race, especially in Europe, was greatly

accelerated, and largely through the use of iron, which has felicitously been called the "king of metals."

(*To be continued*)

While it is the author's intention to incorporate into this series everything of importance connected with the metallurgy of iron and steel, his chief aim will be to make the description as graphic and lucid as possible. In the matter of illustrations neither time nor money will be spared to make these of superlative interest. — *Editor.*

THE MANUFACTURE AND CHARACTERISTICS OF WROUGHT IRON *

By JAMES P. ROE, Pottstown, Pa.

I. Introduction

THOSE who deem the subject of this paper an old and superseded one may recall with advantage the words of the great proverb-maker, bidding us to seek the new in the ashes of the old.

The manufacture of wrought-iron began with the small hearth built upon an eminence, and relying on the wind for blast. Next came, either the hearth about 12 inches in diameter by 2 feet in height, blown by a man operating two goatskins for bellows, or a hearth of greatly varying diameter and about 10 feet high, depending for its blast upon natural draught. The former appeared in India, the latter in Burmah; and both were in operation until quite recently, though their origin is lost in prehistoric times.

The Catalan forge was the evolutionary descendant of the foregoing, and the parent of the *Blase-ofen*, which in turn led to the high bloomery or "Stückofen," the father of the blast furnace, as a producer of cast iron.

The production of cast iron checked the growth of the direct processes and led to the introduction of various hearths, such as the Walloon, for low-silicon irons, and the South Wales

* American Institute of Mining Engineers, May, 1905, meeting.

process, combining the run-out fire with the finery, for higher-silicon irons. Some of these are still in operation in localities possessing the necessary raw materials, and their product is used for purposes requiring wrought iron of exceptional quality, the supply of which is still smaller than the demand.

We have to look back but a century and a quarter to see the introduction of the puddling process by Henry Cort; a process which, reinforced by the iron-oxide bottoms and fettling of Hall, was not less revolutionary in character, and more revolutionary in effect, than any other single step in the metallurgy of iron.

Cort was the first to avoid contamination of the product through contact with the fuel, thus increasing the available fuel supply, and permitting a limitless variety of forms for the furnace. In conjunction with Hall's improvements, his process was the first, and still remains the only one, which can furnish a good product from pig irons relatively high in silicon, phosphorus and sulphur. Other processes can only take care of one, or at the most two, of the metalloids named. The vastly increased supply of iron ore thus made available had much to do with the supremacy in the iron manufacture so long held by Great Britain, while it promoted also the industrial progress of other nations.

The circumstance that pig irons high in phosphorus and sulphur may be used in puddling has more than an immediate commercial significance. In view of the immense and ever-increasing consumption of iron, there must be a limit to the purer ores and fuels available; and a process in which not only phosphorus and sulphur can be eliminated to any desired extent, but the finished product of which may, if wished, retain four times as much phosphorus as good steel, and yet be a thoroughly reliable material for use, is certain to play a part in the fate of nations.

The puddling process as carried out by Cort, and later known as "dry puddling," was effected upon a sand bottom and was open to the objections: (1) that the oxidation of the metalloids was effected by atmospheric action, resulting in high loss; (2) that the volume of cinder as a receptacle for oxidized impurities was small, and hence the range in character of pig iron available was limited; and (3) that, as a consequence, various

kinds of so-called " physic " were employed, resulting in an uncertain product.

The puddling process of to-day, known as the " pig-boiling process," and invented about 1830 by Joseph Hall, consists in the use of relatively infusible oxides of iron for the bottom- and side-fettling of the hearth. Its results are smaller loss of metal, greater output of more certain character, the possibility of using gray pig, and the furnishing of the " physic " that had so long been sought.

The process is both simple and beautiful. Simple, in that the fettling or " fix " forms a reservoir of relatively pure oxide of iron which is automatically drawn upon by the cinder of the bath for correction: that is, the higher the silica of the bath the greater its draught upon the relatively basic sides and bottom, to produce a final cinder, low and constant in silica, which is the factor controlling the phosphorus and sulphur of the product from a given grade of pig iron; beautiful, because the reactions, or their immediate effects, and the crystallization, are all plainly visible and well defined.

The process consists, essentially, in the removal from molten pig iron of nearly all its carbon and silicon, and most of its phosphorus and sulphur, by agitation in the presence of a suitable cinder, and gases of the right composition and temperature; and, finally, by crystallization, due to the greater infusibility of the iron as the metalloids are oxidized.

It demands of the puddler a reasonable degree of skill, and a kind of labor which, though healthy, is very severe. The necessity of such labor has long been recognized as the great practical difficulty and expense of the process; and numberless mechanical devices have been proposed for its diminution, but, thus far, without any marked degree of success.

II. Mechanical Puddling

The attempts at mechanical puddling may be summarized in four general classes:

1. The use of hollow rabbles operated by hand, through which air or steam (sometimes both) were forced into the bath. These involved complications, a necessarily high loss of iron, and little, if any, saving of labor.

2. Stationary furnaces, such as Clough's mechanical puddler, resembling in general outline the ordinary puddling furnace, with rabbles operated mechanically. The objections to this type are its complication, and the fact that it is applicable only to the puddling period proper, and is in the way during the operations of fettling, charging, balling and drawing. In fact, it cannot satisfy the proper requirements for a successful mechanical device, which demands either constant motion, or a constant cycle of motions, which, in turn, call for uniform shape and conditions; whereas, in a puddling furnace, these are ever varying.

3. Revolving furnaces, represented by two distinct types, the Danks and the Pernot, and their respective modifications.

a. The Danks furnace consists of a stationary fire chamber, a cylindrical hearth revolving about a horizontal axis, and a removable flue section, giving access to the hearth for charging and drawing. The advantages of this furnace, which came so near success as to mislead many acute experts, consisted in reducing the labor of puddling and balling, thoroughly agitating the heat, and working on a hot bottom. Its disadvantages were: the excessive time and labor expended in fettling, the difficulty of drawing the heat, the troubles connected with the lining of the revolving portion alternately forming the roof and the hearth, and, worst of all, the balling of the heat before all the iron was "ready," which produced blisters. The product is only available as open-hearth resmelting-stock, for which purpose it is used, in small quantities, to-day.

b. The Pernot furnace has a hearth like a frying-pan, which revolves round an axis slightly removed from the vertical. This slight inclination failed to impart sufficient agitation to the bath, and collect the crystals into a ball. Hence the rabble and paddle were resorted to, which, in conjunction with the same means of fettling and drawing, as in the ordinary puddling furnace, put the Pernot upon the same plane, plus some complications.

4. The oscillating furnace, operating on either a longitudinal or transverse axis, which held the germ of successful mechanical puddling. Some furnaces of this type, however, were hampered by too narrow mechanical limitations, others were too complicated, and all of them have hitherto proved incapable of effecting the whole of the process.

The advances in puddling thus sketched have been disappointing, and not at all in keeping with the progress achieved in blast-furnace practice and steel making. This may be explained in part by the vast technical knowledge applied in recent years to the latter lines, leaving the puddling mills largely to the "practical" men, who have worked their way from puddlers to foremen, and, possibly, to superintendents, without becoming emancipated from the traditions to which they were born.

III. Reactions of the Puddling Process

As already remarked, the puddling process permits the use of irons of greatly varying composition. My experience covers irons containing as much as 3 per cent of silicon and of phosphorus, 2.5 per cent of manganese, and 0.35 per cent of sulphur, though, of course, not all in the same pig iron. In all these cases, iron was produced that would weld freely, and showed no cold- or red-short tendency. It is not my intention to convey the impression that such extreme irons are desirable, on the contrary, they are costly in time, labor and iron loss. For rapid work, good yield, and fitness for ordinary uses, a desirable composition would be about 1 per cent of silicon, a somewhat smaller percentage of phosphorus, 0.1 per cent of sulphur and 0.5 per cent of manganese. For special grades, it is necessary to select the pig in each particular case.

The various iron oxides, charged as fettling, flux and oxidizing agents, should be characterized, in the order named, by infusibility, fusibility and the ability to be readily reduced, for the part they respectively play in the operation. The flux, as the material directly forming the cinder, must be present in sufficient quantity to receive the oxidized metalloids, and low enough in silicon to retain them as the temperature of the bath increases. This cinder is the vehicle for oxygen, whether supplied by roll-scale, ore, or the oxidizing gases of the furnace; it protects the puddled mass from undue oxidation by the gases; and, finally, it forms the welding cinder. Its composition is changed during the process by additions, by reactions upon the fettling and the bottom, and by the condition of the fire and position of the damper.

The control of the volume of cinder, in the various stages of

puddling, up to the finished product, may be mentioned here. Throughout all these stages it is primarily controlled by its composition as effecting its fusibility. In the ball when drawn it is controlled largely by temperature at the time of going on high-boil and at the time of drawing, this temperature, at both periods, being chiefly governed by the damper. In the shingled ball it is controlled by the amount of work or pressure, the cinder being generally smaller in amount when a hammer than when a squeezer is used. In the puddle-bar, and in the finished product, it is dependent upon the reduction in area and the rapidity of this reduction. These conditions put the process thoroughly under the control of the operator.

High cinder-contents are desirable for free welding, for such purposes as pipe making, etc., and low cinder-contents when the product is to be subject to severe physical strain.

The order and proportions of the oxidation of the principal metalloids are shown in the diagram, Fig. 1.

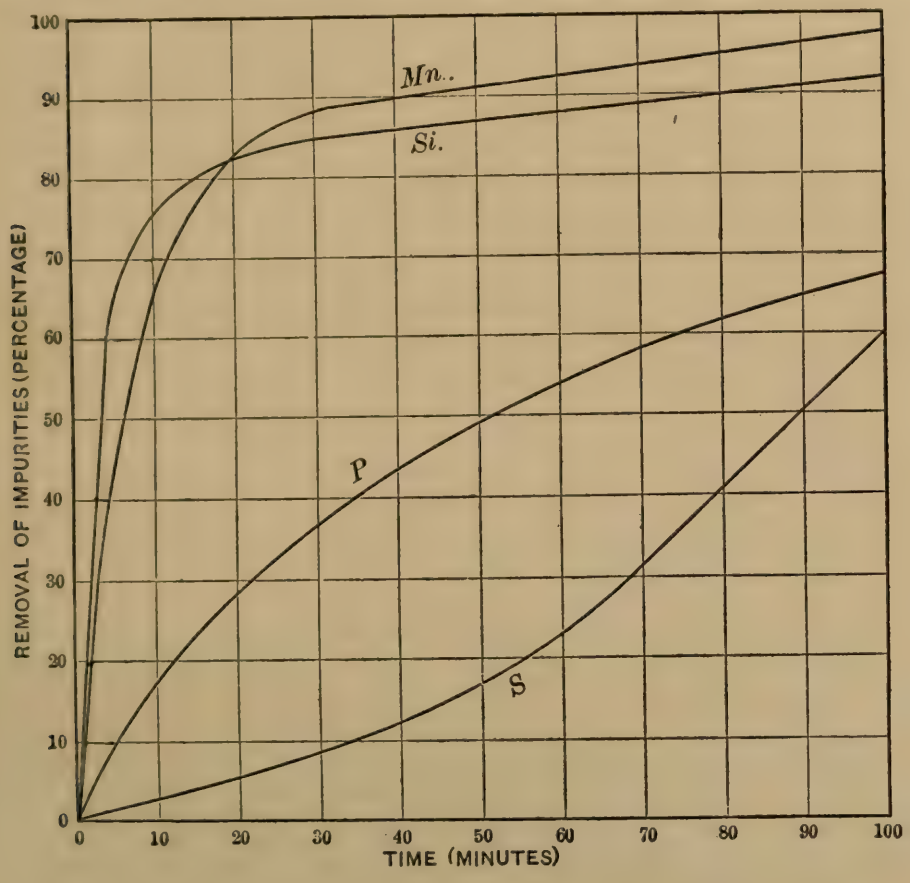
The object of agitation, which is ordinarily accomplished by the rabble, is, to produce as uniform conditions as possible throughout the bath, to bring into intimate contact the cinder and iron, and to prevent as far as possible the settling of the iron, in a partly refined condition, on the relatively cold bottom, and its becoming, as a consequence, too cold on the under side. This occurs in a measure during the "drop," particularly in large furnaces, and necessitates "turning."

Small heats, such as are still worked at Low Moor, England, are best adapted for uniformity of product, since the workman has not the physical strength and endurance to agitate the larger baths efficiently, though he obtains material assistance from a good "high-boil." Another disadvantage in large furnaces is the necessity of starting to draw "young," since otherwise the later balls are subject to severe loss. The irregularities thus produced are, however, largely overcome by the subsequent treatment of piling and reheating. Piling operates as a fairly efficient mixing by the natural law of chances; and reheating helps, by maintaining the iron at a temperature, and for a period, which permits both the oxidation of the carbon of the "young" iron and the reduction of some of the cinder present. Hence, the small pieces of which an iron pile is formed are desirable under existing methods of producing pud-

dled iron. But piling has also its disadvantages, in the production of laminations, due to carelessness, or lack of means or skill, and in the high cost of handling loose piles.

IV. The Structure of Puddled Iron

By reason of decreased fusibility through the elimination of carbon puddled iron crystallizes (" comes to nature ") at a lower



Removal of Impurities from Iron during the Puddling Process

temperature than steel. Each grain or crystal is surrounded by an envelope of cinder, which, when the clusters are dense, fills the intervening spaces. The greater part of this cinder is then hammered or squeezed out, and the succeeding operation of rolling elongates the crystals into what are commonly known as fibers, each fiber existing in a matrix of cinder. This fibrous formation in a matrix of ferrous silicate is the controlling characteristic of wrought iron, and the source alike of its virtues

and its faults. The fibrous structure can be distinctly seen under the microscope at various powers, and often with the naked eye. It is, perhaps, more correctly described by Professor Howe, who says: " I understand that this ' sort of fiber ' is more apparent than real, the grains themselves being equi-axed, yet separated into quasi-fibers by layers of slag. . . . " * Admitting the correctness of this remark, each series of crystals forms an integral structure, which has to be ruptured separately, producing, in every-day practice, results analogous to those we would look for in a true fiber.

Many instances of the arrest of fracture by the fiber occur in the experience of most engineers, with shafts, bolts, chain-hooks, etc. An illustration recently came under my observation: About two years ago a shear cam-shaft, 9 inches in diameter by 48 inches between journals, was bent about 0.5 inches at one side of one of the two cams, producing a crack about 2 inches deep and open almost an eighth of an inch. The lateral movement of the large spur-wheel, due to the bend, was carefully noted, and measured at frequent intervals to learn whether the fracture was extending. As it did not extend, and no convenient opportunity offered for straightening, the shaft ran till July of last year, when it was taken out, straightened and replaced. It is doing good work, and running true to-day. Had it been steel, it would have been necessary to take it out at once, and, after straightening, anneal it; even then, a greater risk would have been run than with wrought iron.

Drive pipes for wells furnish another illustration. Wrought iron withstands the shock of driving at the threads, whereas steel breaks off at the root of the threads.

A blast-furnace plant of two stacks had an experience bearing upon this question. One stack was erected about thirty years ago, with a shell of wrought-iron plates; the other, about four years ago, with a shell of basic open-hearth steel plates. Both were evidently subjected to the same character of strains, and in approximately the same position. The wrought-iron shell bulged out under strain, but did not crack; while the steel shell suffered a vertical rupture extending about 20 feet, and not following to any marked degree the lines of the riveted joints.

* " The Metallurgy of Steel," by Henry M. Howe, p. 193.

Physical tests of steel made in the laboratory on an 8- or 10-inch section give results which superficially appear to be superior to those of wrought iron, particularly in the feature of elongation. But when studied with greater care the elongation is seen to be largely concentrated, and not so uniformly distributed throughout its length as is that of iron.

This tendency to concentrated elongation in steel, and to more widely distributed elongation in wrought iron, is shown in their respective tests, in full-sized sections, for eye-bars in bridges, the specified elongation being the same for iron and steel in a length of 10 feet. The following are results of such tests:

	Elastic Limit	Ultimate Strength	Elongation, per cent		Reduction of Area
	Lb. per sq. in.	Lb. per sq. in.	In 12 in.	In 18 ft.	Per cent
Iron . . .	31,550	48,810	23	15.22	28.30
Steel . . .	33,150	59,260	39	14.40	51.50

There is greater general confidence in welded articles made of iron than of steel. This is well founded: the cinder present in iron, and its low carbon content, naturally facilitate welding. This receives further confirmation from the fact that, as the carbon is increased in steel, the uncertainty of a good weld becomes greater.

V. Resistance to Oxidation

That wrought iron resists oxidation better than steel is becoming the general opinion of those who have studied the question under actual working conditions. The difference is naturally more apparent in thin objects, such as corrugated roof-sheeting, tin plate for roofing, and the like; but its influence is the same regardless of mass. The difference in the life of light sections is about as five to one in favor of puddled iron.

The explanation of this resistance to oxidation is twofold:

1. The cinder, a ferrous silicate, enveloping each fiber, is much attenuated by rolling, and in that condition is elastic. A piece of iron fresh from the rolls is covered with relatively thick scale, which will readily crack off to a large extent, exposing a

surface of iron fibers with its intervening cinder. These fibers oxidize somewhat rapidly, leaving a finely corrugated surface of cinder, which resists further atmospheric action, as may be seen in heaps of scoriæ from old hearths, believed to date from before the Christian era. Being elastic, it resists for considerable though varying periods; but eventually it cracks off under vibration, expansion and contraction, or mechanical wear. The cycle is then repeated and so on.

2. Puddled iron is a mechanical combination of two substances, iron and cinder, which offer differing resistances to such pressure as that of rolls or hammers. The result is a rough surface, which forms a more lasting bond with any protecting agent, such as tin or paint, than the smooth surface of steel, which does not aid in any way the adhesive qualities of the protecting agent.

In connection with the question of oxidation, I may instance the experience of a large tube works, carrying a considerable stock of iron tubes, and accustomed to take from and add to the top of the stock-pile, without regard to the tubes in its lower part, knowing that these, when ultimately reached, would be found to be corroded uniformly over their whole surface, but could be re-rolled to a lighter gauge, producing perfect tubes. After beginning to make steel tubes, they followed the same practice; but these tubes were found after re-rolling to be pitted through, and therefore valueless.

I am indebted to Dr. Raymond, secretary of the Institute, for the suggestion contained in the following communication:

"In preparing your paper for the press, I notice that you have omitted to mention, in connection with the question of the more rapid oxidation of soft steel, a chemical reason, namely, the presence of manganese in that metal. Many years ago, as consulting engineer of the firm of Cooper, Hewitt & Co., I approved the substitution of low-carbon steel for wrought iron, for certain articles of manufacture. The immediate result was complaint from both consumers and selling agents, that these articles rusted so soon as to look old even upon delivery. A careful investigation, conducted for the firm by the late Dr. T. M. Drown, located the source of this trouble in the manganese of the low steel, or 'ingot-iron.' In that particular case the rapid surface corrosion probably did not affect the real usefulness of the articles.

But it may easily be inferred that, when a coating of tin, zinc or paint is applied to a sheet of metal a very slight extra liability to oxidation in that metal may set up a series of chemical and galvanic reactions of destructive character.

"I have had recent occasion to realize with surprise and consternation the imperative necessity of frequent repairs to roofs, pipes, etc., of tinned or galvanized iron. My trusted mechanic declares that all his customers are similarly affected, and protests that he can no longer obtain anywhere materials of this class as durable as they used to be. He thinks that something is the matter with the processes of coating with tin or zinc; but I shrewdly suspect that the trouble lies in the manganese of the metal coated, and in the series of reactions which its easy oxidation initiates.

"It seems to me that the 'pitting' of steel, to which you refer, is directly due to manganese."

VI. Defects of Wrought Iron

Under this head we have to consider transverse weakness, lower ultimate strength, laminations and high labor cost in production.

1. Transverse weakness is inherent, though less marked as the cinder contents are reduced.

2. Lower ultimate strength and elastic limit, demanding (for the same factor of safety, and if the possible effects of the "pitting" of steel be ignored) a greater section for a given strain, is also an inherent weakness, so long as the product is made from built-up piles, requiring low carbon as an essential condition for good welding.

3. Laminations, due to imperfect welding, are commonly the result of inefficient machinery or lack of skill. This defect also is inherently associated with the use of built-up piles, especially when these are made, wholly or in part, from scrap of miscellaneous character. I recall an instance in which a lot of 1¼-inch "rounds" were ordered to be made for special bolts, from muck-bars only. While cutting them to length on the anvil we noticed that, after superficial nicking, some pieces fell off, even without bending. Upon investigation, the so-called "iron" was found to include pieces of hard steel rail,

fairly well defined in form, and surrounded by soft wrought iron, presumedly "muck-bar," which peeled off with the freedom of a banana-skin, the exterior and the core not being welded together.

4. The high labor cost of production is probably the principal cause which has checked, during recent years, the legitimate increase in the use of wrought iron. It is constantly receiving greater emphasis, as the younger generation of workmen, with greater educational advantages, turns away from arduous manual toil, and particularly from the opprobrium attached to the term "puddler," as indicating a relatively servile and ignorant class. This stigma has existed from time immemorial in India, where the iron-worker is ranked in the lowest caste. The severity of the work, together with the inferior social status of the worker, have depopulated puddling mills in this country and England, and caused, in certain districts, the abandonment of puddling.

With the exception of relative transverse weakness, all the above shortcomings of wrought iron are due to the method of manufacture, rather than to inherent qualities of product. Iron puddled in large masses by mechanical means, and rolled direct, as soft steel is, would give us fibrous structure, resistance to oxidation, high tensile strength, low cost, and the absence of laminations. Such a material would cover the field now jointly held by puddled iron and soft steel, even to the possible use of the latter for rails.

VII. Conditions Essential to Successful Puddling

The conditions necessary to produce such iron are: (1) a large unit of manufacture; (2) adequate mechanical means; (3) cinder of proper composition; (4) a flame of the right composition and temperature; (5) a relatively permanent furnace lining; (6) a relatively small loss of iron; (7) simplicity of means and method.

1 and 2. Conditions (1) and (2) are the chief factors (indeed, if we consider Bessemer steel alone, the only ones) in the low cost of steel manufacture. These two conditions, introduced into the production of wrought iron, would have a like effect upon its cost. I will consider later the means of effecting this end.

3. As already shown, the right cinder for the puddling process is largely produced from, and corrected by, the oxides forming the sides and bottom of the hearth. It is, however, evident that the purer oxides of iron are inert while in position, and only become active after absorption into the bath. Hence, when suitable oxides are introduced in the form of cinder, ore, and roll-scale, there is no need of drawing upon the bottom and sides, provided these latter are of such nature as to resist the chemical action of the cinder and the temperature of the gases.

4. The proper regulation of the flame is essentially a simple matter, presenting difficulty only when associated with the motion of the furnace (if the latter be movable).

5. The lining offers a somewhat complex problem, both metallurgically and mechanically. It must resist the chemical action of a compound cinder, the friction of the mass as the iron comes to nature, and a somewhat high temperature. Moreover, in a mechanical furnace, it must maintain its position throughout the movements of the furnace itself.

6. The minimum loss of iron is secured by the reduction of some of the iron oxide additions, resulting in an actual gain of weight of the puddled mass, over the pig charged, in an ordinary puddling furnace. This gain is exceeded by the final loss, due to the delay in the period of balling and drawing. By reducing the period of drawing, as by discharging the whole mass in one piece, this loss may be avoided, and a possible net gain effected.

A mechanical puddler, erected at Pottstown, Pa., and fulfilling the conditions above stated, was described by the writer at a former meeting of the Institute.* To that description, the reader of the present paper is referred.

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* "Puddled Iron and Mechanical Means for its Production," Philadelphia meeting, May, 1892, Trans., XXXIII, 551.

THE THERMIT PROCESS IN AMERICAN PRACTICE *

By ERNEST STÜTZ

JUST a year ago the first Thermit was manufactured in this country and the applications developed in Europe by Dr. Hans Goldschmidt, at the works of Th. Goldschmidt, Essen-Ruhr (founded 1847), were transplanted to American soil and have since blossomed forth under the fostering care of American ingenuity.

The principle of the Thermit process can now be said to be known to the technical world, and it will be sufficient to state that through the ignition of finely divided aluminum and metallic oxide a reaction is started which produces heat at about 5400° F. and at the same time reduces the iron oxide to a metallic iron almost free from carbon, in a highly superheated liquid state. Thermit steel has practically twice the temperature of open-hearth steel, and a correspondingly greater fluidity. By suitable additions of carbon, in the form of steel punchings, chilled iron shot or ferro-silicon, its hardness, and, by addition of manganese, its toughness, can be increased to any suitable degree.

The following analyses will confirm this:

ANALYSIS OF THERMIT STEEL

ILLINOIS STEEL COMPANY, THE ROOKERY, CHICAGO, ILL.

Carbon	Manganese	Silicon	Sulphur	Phosphorus	Aluminum
0.05	0.10	0 204	0.04	0.05	0.18

Tensile Strength, lbs. per sq. in.	Elongation	Contraction of Area
59,320	25.33 per cent	59.6 per cent

PENNSYLVANIA RAILROAD, ALTOONA

Thermit Steel with addition of 2 per cent carbonless manganese 5 per cent iron punchings (calculated on amount of Thermit)

Carbon	Manganese	Silicon	Sulphur	Phosphorus	Aluminum
0.102	2.330	1.227	0.034	0.070	——

Tensile Strength, lbs. per sq. in.	Elongation, per cent in 8 in.	Appearance of Fracture
91,600	21.5	Silky

* Read at the June, 1905, meeting of the American Society for Testing Materials.

The first is one of pure Thermit steel; the other of the steel in the riser of a welded-steel locomotive frame, drawn out under the hammer into a bar some three feet long and turned down and broken.

The simplicity of outfit and manipulation and the speed with which the reaction does its work are its chief recommendations for industrial purposes.

In a crucible some 20 inches high and therefore easily transportable, in half a minute can be produced 30 pounds of liquid steel, so hot that it will melt a steel bar of 4 inches square section and fuse with it to one homogeneous mass.

The essential characteristic of Thermit is that it welds by fusion, and, by reason of this fact, calls for the foundryman's experience more than the blacksmith's. Its success depends on the proper material, shape and condition of the mold.

The mold into which the contents of the crucible are run must be of refractory material. The general instructions must, of course, be broad and cannot go beyond stating that a mixture of equal parts of sharp sand and ordinary brickmaker's clay has given satisfaction. The formula has been varied sometimes, according to local conditions, in some cases flour, in the proportion of 6 to 100, being used as binder for the sand. Some shops have already evolved their own particular formulas, which they treat as secret. The mold always must be dry — *burnt* dry. In some cases, for instance, at the Elkhart shops of the Lake Shore & Michigan Southern, the difficulty has been overcome by using firebrick cut down to size. This certainly overcomes the question of drying molds.

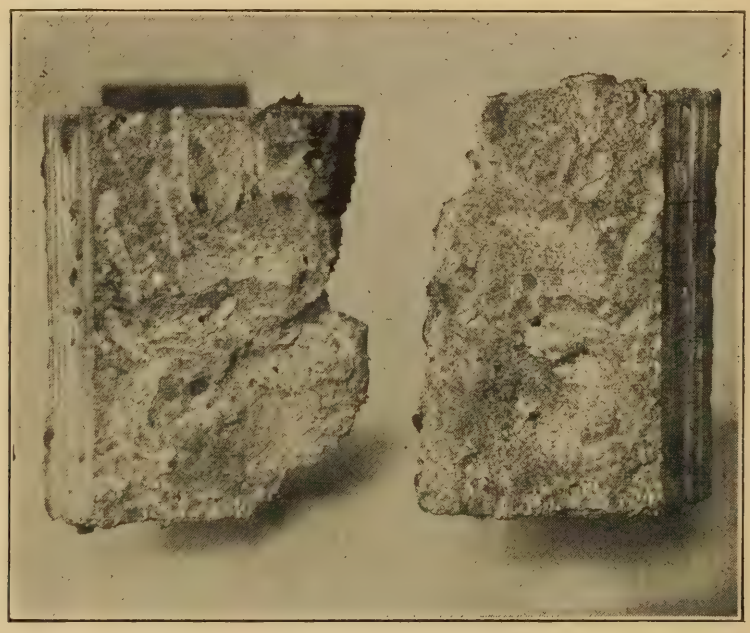
The shape of the mold must next be considered. It must be so constructed that the steel flowing down through the gate will not strike direct on to the casting or forging, but will flow underneath the lowest part and rise around and through it. What is required is good circulation for the Thermit steel. It must flow around all the welding surfaces, and as it gets chilled in contact with these it must be driven up into a riser and be followed by a sufficient supply of fully heated Thermit steel to effect the actual weld, which takes the shape of a collar or reinforcement, cast on or over the fracture.

The mold must, therefore, allow (1) for a gate; (2) for a collar, shoe or other reinforcement on the surface of the welded

piece and overlapping the edges of the break or joint; (3) a riser; (4) a skim gate, to prevent the slag from getting mixed with the steel.

The formula for calculating the amount of Thermit must also allow not only for the cubic space of this reinforcement, but further, for again as much Thermit, to supply the contents of gate and riser.

These are the general instructions for welding, for instance, *locomotive frames* — a problem which some thirty railroads in this country have investigated with more or less success. These



Break of Welded Bar, $2\frac{1}{2}$ x $2\frac{3}{4}$, after Pressure of 50 Tons

frames are of wrought iron or cast steel and vary from $3\frac{1}{2}$ x $3\frac{1}{2}$ to 5 x 6 inches in section. They are very liable to break and their repair without dismantling the engine means a very large saving per engine. It has been stated that an engine the frame of which is repaired in the forge remains a fortnight out of commission and the actual weld costs $250 to $300. The work by Thermit can be done comfortably in three or four days, at a cost of about $50.

In reply to a circular letter of inquiry, about twenty railroads have supplied data, which, however, cannot be considered

complete, as some of the most regular and extensive users of Thermit did not care to supply the information asked for.

The first successful weld it has been possible to get a record of was made by Mr. Sanderson, superintendent motive power, Seaboard Air Line, on October 19, 1904. This engine has continued in service ever since. It is one of eight engines welded on that road which has given satisfaction, which speaks highly for the care used at the Portsmouth shops in handling a new and therefore difficult problem.

Another series of successful welds is reported by the Boston



Welding Locomotive Frame: Ready for Ignition

& Albany Line, where Mr. Fries welded five engines quite successfully, one being in continuous service since the end of November. One, welded in the jaw, broke again, but four inches away from the weld.

Of late the Lake Shore & Michigan Southern has shown great interest, and its perseverance has been crowned by success in some very good welds at their Elkhart shops, about which Mr. Webb read a very interesting paper at the last annual meeting of the American Foundrymen's Association, giving a full account of each step in the operation. On a preliminary test, a welded bar $2\frac{1}{2}$ x $2\frac{3}{4}$ stood a pressure of 50 tons on supports 20 inches

apart, before breaking, and that after two sides of the reinforcing collar had been machined off.

In all there are records of thirty engines with welded frames that have been in service for three months or longer. Failures are recorded only in isolated instances and are assignable to two different reasons:

First, wrong construction of mold.



Locomotive Frame: Welded in the Jaw

Second, insufficient Thermit; in other words, insufficient circulation — therefore, insufficient fusion.

For those familiar with the process, a weld that breaks on account of lack of cohesion at the welding surface is attributable under all circumstances to lack of experience or care, except in one particular case.

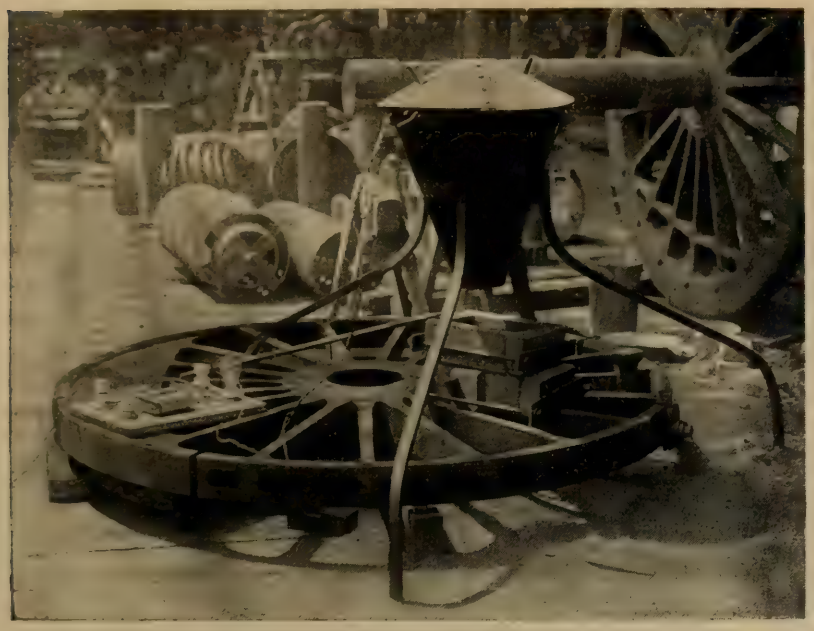
It is possible for Thermit welded frames to break in spite of proper execution of the work. The original break is due, in the first place, to a structural defect. With the break in such

a position as to necessitate the entire removal of the reinforcing collar, it is too much to expect the mere bridging of the broken ends by Thermit steel to overcome this innate weakness.

An important factor in success in welding locomotive frames is to allow for equal shrinkage of parallel parts; also, wherever possible, to spread the ends apart in order to let them come back when the iron begins to set.

Another operation of interest to railroad men is the welding of spokes of drivers.

In making tests of the metal of such welds, the Chicago,



Welding Spoke of Locomotive Driving Wheel

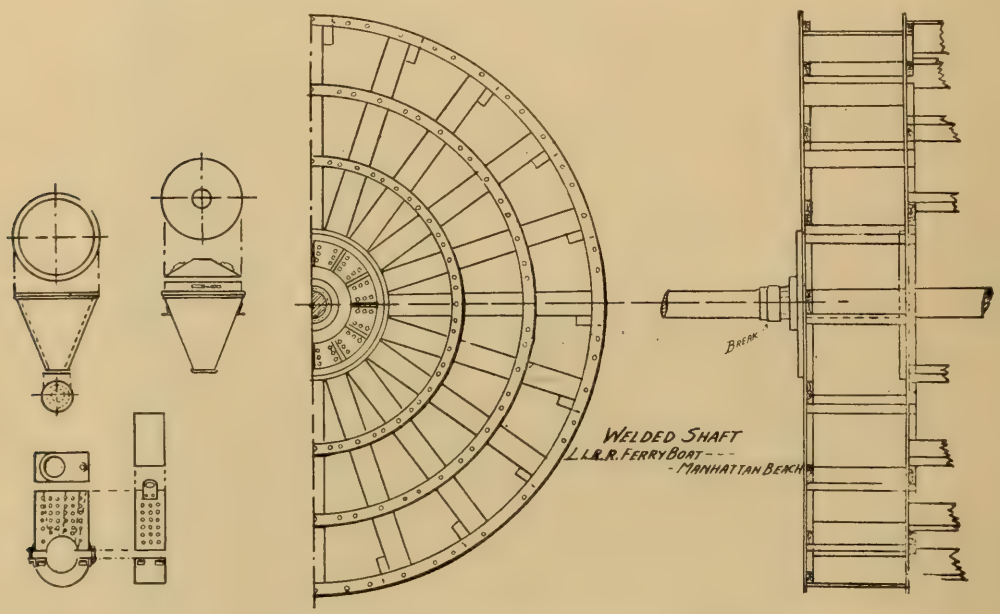
Milwaukee & St. Paul R. R. found a tensile strength of 93,900 pounds per square inch. The analysis agreed with that of the Pennsylvania R. R., with the exception of manganese, which in this case was only 0.74.

Next came repairs in *marine engineering*, which are mostly successes obtained by Mr. Des Anges, superintendent floating equipment of the Long Island Railroad.

A 12-inch crank shaft (13⅝ inches at point of fracture) of the ferry-boat *Manhattan Beach* was welded with 400 pounds of Thermit. The break was in the " wheel center," necessitating

the shifting of the center to a new position and shortening the paddle boxes. The shaft was pre-heated, by a charcoal fire and hand-blower, to black heat. To protect the woodwork of the ferry-boat an asbestos curtain was hung around the crucible, which served its purpose admirably. The ferry-boat has been in uninterrupted service for nearly three months, and continues so now.

A rudder stock 5 inches in diameter was welded with 50 pounds of Thermit and 10 pounds of punchings. The collar in this case had to be entirely removed, but the welded rudder-stock has now been in service for eight months.



Weld of Crank Shaft, *Manhattan Beach*

On the Great Lakes, through the enterprise of Captain Johnson, at that time with the Dunham Towing & Wrecking Company, the rudder shoe of the tugboat *Schenck* was welded, 125 pounds of Thermit being used. The weld was sound — in replacing the propeller a chain broke and the propeller dropped on the welded shoe without injuring it.

Some important repairs of *gray iron castings* are also reported. At the Renovo shops of the Pennsylvania Railroad a hydraulic wheel press was repaired, the part welded having to stand a pressure of 60 tons per square inch. The original "strong back" holding the wheel against which the axle was

pressed was not strong enough for the purpose until repaired by Thermit.

Cylinder covers are also repaired by Thermit and have been made as good as new.

Work with gray iron castings requires more experience, in regard to pre-heating and cooling down gradually — more Thermit is necessary to effect the weld, on account of a hard, glassy scale on such castings, which resists fusion, and an addi-



Weld of 5-in. Rudder Stock

tion of ferro-silicon (about 2%) is advisable to prevent hard spots at the lines of junction between Thermit steel and cast iron.

The most important application of the Thermit process is for making a *continuous rail.* The process having been brought to a high state of perfection in Europe before coming here, there was little room for changes in practice. About 30 different cities are investigating the process in actual operation and about 5,000 joints have been put in up to date. All these roads recog-

nize in the Thermit process the best and simplest means of joining rails for electric traction, as long as care is taken to do small and simple things right. Competitors in the field of rail welding may send out fanciful blue-prints about broken joints, to create unfavorable impressions, but such manœuvers prove nothing beyond the fact that they admit the success of the Thermit process in this field.

Some tests may be of interest. A heavy double trolley car was taken over a welded joint with supports 13 feet away, without breaking it.



Welded Rudder Shoe, Tugboat *Schenck*

To decide whether the head of the rail got softer, micrometer caliper measurements were taken of depressions made under equal blows of a steam hammer, by a blunt tool hardened at the head, $\frac{1}{4}$ inch in diameter.

One-half inch away from the joint the depression was 0.1432 inches.

Three feet away from the joint the depression was 0.1596 inches.

The electric conductivity of the Thermit joint is recognized to be higher than that of the rail, due to increase of area, and is permanent.

That *steel foundries* should have been the first to recognize the possibilities of liquid steel that can be produced anywhere in half a minute goes without saying. There are already several of the largest with whom Thermit is as much a necessity as foundry sand. Some prefer — for no apparent reason — not to disclose the fact that they repair faults in castings by Thermit, but all can openly admit that they use it to reduce the size of their risers, an application which, through its simplicity, recommends itself to all foundries, — gray iron as well as steel. Thermit thrown loosely or in a paper parcel on steel will ignite and



Welding Trolley Rail at Holyoke, Mass.

keep the contents of the riser fluid even after the metal has become plastic in the casting. Liquid cast iron will only ignite Thermit in the presence of the ignition powder.

The application of Thermit to *reduce the piping in ingots*, although very simple in itself, necessitates some liquid steel being held in readiness to fill up the piping after the solidification has been interrupted by a thermit reaction. This should not be impossible to arrange.

RIEHLE BROS., TESTING MACHINE COMPANY

TESTS ON MALLEABLE IRON BARS CAST AT PENNSYLVANIA MALLEABLE COMPANY'S WORKS, McKEES ROCKS, PA.

BEFORE TITANIUM THERMIT REACTION

	Dimensions	Ultimate Strength, Pounds	Deflection
No. 1—1	1.000 x .999	4,100	1.00″
1—2	.995 x .999	4,500	.98″
1—3	Lost in anneal		
2—7	1.060 x .998	4,540	1.28″
2—8	1.012 x 1.006	4,610	1.40″
2—9	1.006 x 1.005	4,500	1.40″
	Average before treatment	4,450	1.212″

AFTER TITANIUM THERMIT REACTION

	Dimensions	Ultimate Strength, Pounds	Deflection
No. 1A— 4	1.011 x 1.010	5,920	1.30″
1A— 5	.999 x 1.000	4,260	1.27″
1A— 6	.989 x .995	4,850	1.55″
2A—10	.995 x .996	4,620	1.47″
2A—11	.998 x .996	4,410	1.37″
2A—12	1.011 x 1.000	4,810	1.44″
	Average after treatment	4,811	1.60″

Another branch of alumino-thermics which will be of interest is the *improvement of gray iron castings*, by the introduction of titanium Thermit in the ladles, by immersing it in a cartridge below the surface of the metal. Some experiments, thanks to our fellow-member's, Dr. Moldenke's, kind intercession, were made at the Pennsylvania Malleable Works, with the foregoing results, the bars having been poured out of the same ladles, one before, the other after, the titanium Thermit reaction.

Experiments with lower grades of iron showed the same favorable results.

At the Featherstone Foundry, Chicago, titan Thermit treated test bars showed a tensile strength of 3,550 pounds, against average untreated, 3,250 pounds.

The metal, after treating, is much denser, but can be easily machined.

Incidentally it may be mentioned that by the introduction of a 1½-pound cartridge of ordinary black Thermit into an 800-pound ladle 40 pounds of steel borings can be melted without difficulty.

This necessarily very short account of what is doing in Thermit cannot, of course, cover the entire field of the applica-



Welding Rudder Stock on Tugboat *Schenck* on Marine Railway, Sault Ste. Marie

tions, but will perhaps tend to convince those who had rather be guided by results obtained elsewhere than spend time and money for what they think experiments, and encourage others who are doubtful from lack of experience, by showing them what has been accomplished in actual practice.

THE APPLICATION OF DRY-AIR BLAST TO THE MANUFACTURE OF IRON *

By T. W. ROBINSON

THE international discussion that has been evoked by Mr. Gayley's latest contribution to the annals of iron and steel is a striking testimonial to the value of his paper. If the figures given can be considered typical of what may be reasonably expected from the use of the dry blast, its innovation is bound to prove of the greatest importance. That the problems of cause and effect are intensely interesting, both from their commercial and scientific aspect, is reflected in the widespread interest that has been evinced. Those questioning the sincerity of the Isabella test, or the accuracies of recording the results, will not be considered by those acquainted with Mr. Gayley or his past work. As to the causes for results so at variance with accepted ideas, the discussion has brought out little that is convincing. It is strange that greater stress has not been placed on what Mr. Gayley, himself, has had to offer in the way of explanation. Stated briefly, his reasons for the higher efficiency obtained are, greater uniformity of practice and ability to reduce the heat reserve. The essence, of course, of the Isabella demonstration is that the furnace, working under as strictly comparative conditions as could be devised, showed a saving of approximately 400 pounds of coke per ton of iron through the substitution of dry blast for ordinary blast. The natural inference was that this result must be directly due to the saving of the heat ordinarily dissipated by the usual introduction of the moisture. Calculation, however, shows that the heat units involved in the evaporation and disassociation of the moisture removed by refrigeration represent less than one fourth of the amount of the fuel actually saved. How can such an anomaly be explained? In studying this question one naturally looks, first, to the conditions under which the test was made. We have Mr. Gayley's assurance that every care was exercised to make the conditions under which the furnace was operated strictly comparative. The records at Isabella, which were thrown open to

* Discussions of the paper of Mr. Gayley read by title at the Lake Superior meeting, but first presented at the New York meeting of the Iron and Steel Institute (October, 1904).

inspection, verified this fact. Raw material, equipment and general practice were shown to be practically constant during the test. The only appreciable variable was the character of the blast. Mr. Gayley's paper covered an operation of one furnace for only about six weeks, during which the fuel was reduced approximately 400 pounds. It has been questioned whether so short a test might not easily lead to erroneous conclusions. Fortunately for the advocates of the dry-blast process, further experiments at Isabella have corroborated the initial returns. Since the paper was presented the writer has examined the records of four consecutive months on dry blast at the two adjacent Isabella stacks. During this period both were operated under practically identical conditions save that one was run with dry blast and the other with ordinary blast. The dry-blast furnace showed an average coke consumption of 437 pounds per ton of iron less than the other. To make the experiment more conclusive the blast on the two stacks was interchanged, the one formerly on dry air being put on ordinary air and *vice versa*, the practice otherwise remaining the same. In less than a week the furnaces had exchanged places in production and fuel consumption. This further demonstrated that any differences that might have existed in plant and practice were not of much consequence. The logical conclusion is that the refrigeration of the blast must, in some manner, be accountable for the surprising results obtained.

The problem, accordingly, resolves itself — (1) into a study of the effect of the refrigerating process on the character of the blast itself and (2) of the influence of the dry blast on the furnace reaction.

Refrigeration as carried out at Isabella eliminated about three quarters of the normal moisture and materially increased the density of the blast at the blowing tubs. The fuel directly saved by the elimination of the moisture, as based upon Mr. Gayley's figures of 69 pounds of water removed per ton of iron, is equivalent to less than 80 pounds of coke. If we add to this the saving incident to the increased temperature of the blast there is still a large part of the total saving unexplained.

But what effect has the increased density? The records show that, where formerly the engines were making 114 revolutions, the refrigerating of the blast necessitated a reduction

to 96 revolutions. If, to be conservative, we assume the ordinary temperature of the air to be 75° F. and that of the refrigerated blast, as it enters the blowing tubs, to be 22° F., and allow the refrigerated blast to have an increased pressure of 0.3 ounces, due to the use of the auxiliary fan, we find that the actual weight of the air used per unit of time is in the ratio of 100 to 93.6. In other words: By slowing down the engines from 114 revolutions to 96 revolutions there was a reduction of a little over 6 per cent in actual weight of air blown. In volume the reduction at the blowing tubs amounted to 15.8 per cent. This, however, under equal furnace pressure, would have been reduced to a difference in volume of 6 per cent at the tuyères had the stoves heated the air, in each case, to a like temperature. While weight and volume did not correspond at the engines they would have done so at the furnace had the stove capacity been sufficient. That the stoves did not, in each instance, heat the blast to the same temperature is merely incidental and not essential to the case in point.

Accordingly, as increasing the density at the blowing tubs does not change the volume of air, or the weight of air, or the weight of oxygen that enters the furnace, if compensated for by lower engine speed, its only appreciable effect is to increase the engine efficiency. The more dense the air the greater the weight that can be blown per revolution, that is all. Hence it is clear that the increased density of blast, due to refrigeration, cannot rationally be offered as a cause for the decreased coke consumption. Further, the only practical result in cutting the revolutions from 114 to 96 was to reduce the blast from 40,000 cubic feet per minute to about 37,400 cubic feet per minute. This is a comparatively small reduction and one, of course, capable of attainment without the intervention of refrigerating machinery.

Mr. Gayley says, that by reducing the revolutions from 114 to 96 the volume of blast was reduced 6,000 cubic feet per minute. He cites this fact in calling attention to the influence that the increased density of the air had upon the steam economy. His statement is correct, but liable to misconstruction unless the material difference in the relation of weight and volume in ordinary and refrigerated temperatures is appreciated. They are, of course, not comparable.

As usually calculated by piston displacement, the difference in the dry and the ordinary blast that entered the furnace was 2,600 cubic feet, not 6,000 cubic feet. Apparently, then, neither increased density nor reduction of blast could explain the balance of the fuel still unaccounted for.

Turning now to the effect of the dry blast on the furnace, we know that its introduction was quickly followed by increased production and decreased fuel consumption. Analyzing the details, it is perceived that the furnace on dry blast ran with lower top temperature, with an increased per cent of carbonic acid in the waste gases, with a less amount of air per unit of coke and with lower pressure of blast. The differences are indicative of lower fuel and are the results of less coke consumption, not causes for it. We note that the iron produced is more uniform in analysis, that there is less slipping of the furnace, that the flue dust has been reduced from 5 per cent to 1 per cent and that, generally, the dry-blast furnace is more regular in its operation than the other. In studying the possible causes for fuel saving, it has been shown that the difference existing in plant and raw material had no appreciable effect. The influence of increased density and decreased revolutions of engines was practically negative. Allowance for the heat equivalent of the eliminated moisture and for the increased temperature of blast does not explain the results that were obtained. One point, however, that has not yet been discussed is, the greater regularity of the dry-blast furnace. That greater regularity ought to follow refrigeration will be apparent, if the large amount of moisture usually introduced is appreciated and the extent of its hourly and daily variations fully realized. If any one questions this, let him consider what the effect would be of injecting at the tuyères a stream of water under a 40-foot head that varies from 0.75 to 1.5 inches in diameter. This is practically what a humidity varying from 2 to 6 grains per cubic foot means when 40,000 cubic feet of air is used per minute, even though introduced as super-heated steam.

By reducing the moisture two thirds or more, and by causing the residue to become nearly constant, the refrigerative process cannot help but have an important effect upon regular work.

Now, it may be considered axiomatic that under any given condition of raw material and equipment minimum fuel will

accompany maximum regularity. It is no uncommon occurrence to see a difference of 400 pounds of coke per ton of iron follow the swinging of a furnace from uniform to irregular work. Ordinarily irregular work is a direct sequence to scaffolding, even though it be embryonic. As to the cause of scaffolding, its name is legion. Lack of uniformity in any of the elements of blast-furnace practice is conducive to a changeable zone of fusion and to accretion. A change of 50° F. in stove temperature will often raise the pressure and sometimes cause more serious trouble. Largely to the extreme variation of moisture in the outer air and in the engine room is, undoubtedly, attributable the fact that there is not a greater difference in fuel between summer and winter. A compilation of the average monthly results for ten years of eight furnaces at South Chicago shows that for June, July and August there was an increased fuel consumption of but 21 pounds of coke per ton of iron over the winter months. As these furnaces were working, during this long period, under conditions that were practically comparative, the result is of more than ordinary interest on account of so many variables being minimized. The possibility of maintaining more uniform conditions through protecting the incoming blast from steam contamination appears worthy of more careful consideration than is ordinarily given.

The blast furnace is an exceedingly rough piece of mechanism, but, withal, a most delicately poised apparatus, when working under greatest efficiency. When normal, its chemical and physical laws are subject to reasonably accurate deductions; but, unfortunately, its regular condition is one of irregularity. This is paradoxical, but just here lies the main reason why Mr. Gayley is obtaining something in practice that theory does not fully explain. From a laboratory standpoint, the reactions involved in iron smelting are simple and well understood. As actually encountered in the furnace they are exceedingly complex and difficult to measure — especially so when there is irregularity.

The question of removing the moisture from the blast is, of course, an old story. Many have considered the subject and discarded it as an unfeasible proposition, not only for want of a proper method but from failing to recognize its latent possibilities upon more uniform practice. Twenty years ago the writer was cognizant of comparative tests simultaneously made by

Messrs. James Gayley, E. C. Potter and F. A. Emmerton, at Pittsburg, Chicago and Joliet, upon the humidity of the air and its effect upon the furnace. That, after so long a study, Mr. Gayley has been able to make the Isabella demonstration, despite practical and scientific discouragement, is a fitting climax to his persistency and ingenuity. Theoretically, the end did not warrant the means. But, in iron smelting, theory has had to be remodeled many times to square with actual results. Numerous reasons and hypotheses have been advanced in the past to prove why it would be impossible to obtain certain ultimates in coke and product, which were later achieved and surpassed, and history repeats itself. The essential reason for the more effective work that followed the replacing of old-time methods by scientific management was the ability to command more uniform conditions. In later years the evolution of furnace practice has proceeded along divergent lines. On the one hand, more perfect mechanical appliances and a better understanding of the principles involved have tended to greater uniformity and lower fuel. On the other, much larger units, heavier blowing and, in this country, the advent of the finer ores from the Mesabi Range, have promoted irregularity and higher fuel.

Because the Isabella furnace was consuming 2,147 pounds of coke before the dry blast was applied, the question has been raised whether the subsequent saving of 421 pounds is not misleading, on account of being based on poor practice. Those who know the facts are aware that 2,150 pounds of coke per ton of iron more nearly represent the average practice to-day in the United States than 1,900 pounds or any less. It is self-evident that a furnace consuming 1,900 pounds would not present the same opportunities for reduction as would one using 2,147 pounds. But the opinion that the Isabella practice was poor is neither warranted by the conditions that existed nor by the results that are generally being obtained in this country. Whether the Isabella results can be considered a fair index of what the dry blast would accomplish elsewhere will depend upon individual conditions. It is certain, however, that the refrigeration process will ordinarily pay a handsome return on the investment, and indications now point to its being widely introduced.

As to the influence of heat reserve, to which Mr. Gayley calls attention, every practical furnace man knows how exceedingly difficult it is to correctly measure the actual reserve that is being carried at any given time. In the Isabella case an examination of the records shows that, during the four or five months of cold-blast practice, whatever reserve was carried lay rather in the burden than in the stoves. As the amount of reserve heat is best measured by the analysis of the iron that is being produced, it is significant that, during the period mentioned, the iron from the furnace with ordinary blast was no hotter than that from the furnace with dry blast. There was more variation in the percentage of silicon, but the average indicated that the maximum possible burden was being maintained on one as on the other. Accordingly, while the question of heat reserve might be an important one, the evidence fails to show that it was much of a factor in the Isabella test.

From what has gone before, the logical conclusion is, that greater regularity superinduced by refrigeration is largely the cause of the extraordinary results at Isabella. This may not be capable of scientific demonstration, but until the usual reactions of the blast furnace can be more accurately measured I am content to rest rather upon actual results and rational conclusions than upon scientific deductions that are antagonistic to facts.

THE INFLUENCE OF TITANIUM ON PIG IRON AND STEEL *

By PIERRE DELVILLE

1. *Titaniferous Ores.* — The ores contain from 10 to 40 per cent of titanium. They are found in immense quantities in Sweden, Norway, Canada and the United States; they are generally exceedingly free from phosphorus and sulphur, and the percentage of iron ranges from 35 per cent to over 60 per cent.

2. *Direct Smelting of the Ores.* — The use of titaniferous ores in the blast furnace has been studied by Rossi, who controverts the opinion that the presence of titanic oxide (TiO_2) in slag renders it more infusible and entails a higher consumption

* Presented at the Mining and Metallurgical Congress, Liège. "The Iron and Coal Trades Review," July 7, 1905.

of fuel. He also holds that the pig iron, which usually contains very little titanium (traces, to 1 per cent) is of good quality, and equally suitable for the Bessemer process and for use in the foundry. Some authors attribute this to the presence of titanium, others to the low phosphorus, and others, again, to the influence of slags containing titanic oxide, in eliminating sulphur. The metal can be used for the subsequent production of armor-plate and for boiler plates, etc.

Titanium has been held to favor the formation of bears and scaffolding, which are more likely due to an excess of lime in the slags. Howe states that cyanides of titanium are formed in the masonry of the hearth, but analyses of the bricks have shown them to consist of almost pure lime. According to Rossi, titanic oxide is totally irreducible by carbon, but it would appear that the highest temperatures of the reducing and fusion zones play an important part in this reduction, and pig iron has been obtained containing 0.07 per cent of titanium, with a blast at 850° C., and a good coke. In this instance the burden yielded about 33 per cent, with 10 per cent of Swedish ore containing 0.42 per cent of titanic oxide, so that a burden of 3 tons was required to yield 1 ton of pig iron. With a hot blast the whole of the titanium passed into the pig iron; if the blast became cooler, and, in particular, if it fell to 700° C., the resulting metal contained traces only.

3. *Titaniferous Pig Iron.* — In what state is titanium present in pig iron? Riley held, in 1872 and in 1880, that, in gray pig, it was often present as a carbide. The presence of graphite is not, however, necessary. White iron, high in carbon, may contain large amounts. Thus, Allen cites an instance of a titaniferous plate containing:

	Per Cent
Combined carbon	2.70
Graphite	Traces
Silicon	1.0)
Titanium	4.15
Manganese	1.37
Phosphorus	0.08
Sulphur	0.09

Shimer (quoted by Howe) says that the titanium takes the form of little cubes of titanium carbide, insoluble in hydro-

chloric acid and in potassium hydrate, but soluble in nitric acid, and non-magnetic. Riley, at the meeting of the Iron and Steel Institute in 1894, reported that the smelting of a Canadian mineral containing 33 to 34 per cent of TiO_2 yielded a pig iron of splendid quality, but costing too much by reason of the enormous quantity of slag produced (six times the weight of the pig iron produced). At the same meeting, Dellwik explained the desulphurization and possibly the dephosphorization of the make, as due to the action of the titanic oxide, but the large production of slag entailed an increased fuel consumption.

Bowron, the chemist of the Norton blast furnaces, which made a specialty of the reduction of these minerals, stated that the pig iron produced cost double that ordinarily produced, and served for mixtures for imparting strength to foundry iron and for open-hearth steel. Similar results were obtained at the Adirondacks blast furnaces where, for years, the pig iron has been used for the production of hard tool steels, samples of which were exhibited in London as far back as 1851. In 1892, Raymond recommended the use of such pig irons in admixture with ordinary foundry iron, for tires of wagons and for making chilled castings.

4. *Ferro-Titanium.* — The Aktieselskabet Titania Company, of Christiania, which owns deposits of the minerals, has smelted them in the electric furnace and proposes to obtain by this method a moderately fusible alloy containing manganese and silicon or aluminum, in addition to the iron and titanium. The use of this alloy appears simpler, although probably more costly than that of Goldschmidt, hereinafter described (aluminothermic process). Rossi has also prepared a series of alloys in the electric furnace containing 10 to 75 per cent of titanium, and has improved the quality of hard crucible steels by adding titanium, thus increasing their malleability and ductility. These results are probably due, as will be seen later, to the influence of titanium as a deoxidizinga gent in the bath of metal, and to the elimination of the nitrogen occluded in the steel, the expulsion of which is favored by the presence of high percentages of carbon. The experiments, repeated by Rossi, gave such promising results that a company was formed to establish works at Niagara for the preparation of these alloys under his patents. The results have not yet been made public.

A French firm has produced a ferro-titanium containing about 45 per cent of titanium by reducing a mixture of rutile (TiO_2) and iron oxide by means of aluminum, at a red heat, in the presence of boric acid, in a crucible. Paul Girod has given the author some particulars respecting the preparation of ferro-titaniums in the electric furnace. The alloys contain about 50 per cent of titanium and 47 per cent of iron.

The effect of titanium on pig iron and steel is very little known. Analysis has shown it to be very difficult to recover the titanium added, and its action has consequently been regarded as purely chemical; the absorption of gases contained in the steel. Cast steel thus treated possesses, however, a great surface hardness, resembling that conferred on quenching, and this can be further accentuated by actually carrying out the latter operation. Several crucible steel makers have, during the past year, used these alloys for the production of self-hardening tool steels, the effect being to increase the surface hardness of these steels, while at the same time diminishing their brittleness. The alloy is very refractory, and becomes with difficulty fluid at the temperature of the electric furnace (3000° to 3500° C.). To get it to mix with the steel in the crucible, it must first be heated to a white heat, and then thrown in while the steel is very fluid, so as to make a homogeneous mixture.

5. *Titaniferous Steel.* — Hadfield considers that not more than 0.3 per cent of titanium should be present in steel, the proportion below which it appears to absorb gas. It is to be remarked, however, that under these conditions a cyanide of titanium is found, which separates from the metal. Guillet, who has studied these steels, has come to the conclusion that the influence of titanium is practically *nil*, and that titanium steels possess no commercial value.

6. *The Use of Aluminothermite.* — Dr. Goldschmidt, of Essen, makes a ferro-titanium with 20 to 25 per cent of titanium, which mixes readily with the bath. Later it was found that the titanium alloys more easily with manganese, but that it is better to occasion this reaction to take place in the mass of the molten metal. The resulting improvement is due to the elimination of oxides and of the nitrogen contained in the metal, and also, the author believes, to the hydrogen which burns on the surface of the bath, with its characteristic bluish flame. In

practice the addition is made by inclosing the alloy (23 per cent of titanic oxide, 45 per cent of iron oxides, 25 per cent of aluminum and 7 per cent of gangue) in a box, attached to a stem, and placing it in the bath of metal. After a few seconds the reaction takes place and lasts about a minute, the temperature of the bath rising and ebullition occurring owing to the escape of gases, to which the subsequent homogeneity of the metal is to be ascribed. Numerous investigations were conducted on samples of metal that had undergone this treatment, the conclusion being drawn that titanium acts principally by expelling the occluded gases, and eliminating any nitrogen, particularly in the presence of carbon.

The influence of arsenic on iron and steel was also the subject of investigation by the author.

PROTECTION OF IRON AND STEEL STRUCTURES*

MEMORANDA OF TESTS

By LOUIS H. BARKER

ABOUT eleven years ago experimental investigation was begun with numerous well-known and established iron paint preservatives, in order to ascertain by actual exposure tests the best one to resist the destructive action on steel structures of sulphurous gases in the form of smoke combined with the moisture of steam, and since that time fifty or more paints and combinations have been tried. Among them were many kinds of asphaltum, rubber, graphite, carbon lead and iron paints, and though the results showed varying degrees of resistance, it is remarkable that even with three coats of paint not one was found that did not show rust in less than a year. Of course, it is to be understood that the exposures were made so as to subject the test bars to the severest action possible in order to obtain the quickest results.

In making the first series of tests new steel plates ten inches square were used. As, however, the adverse conditions we were trying to overcome related to rusty steel, which is more difficult

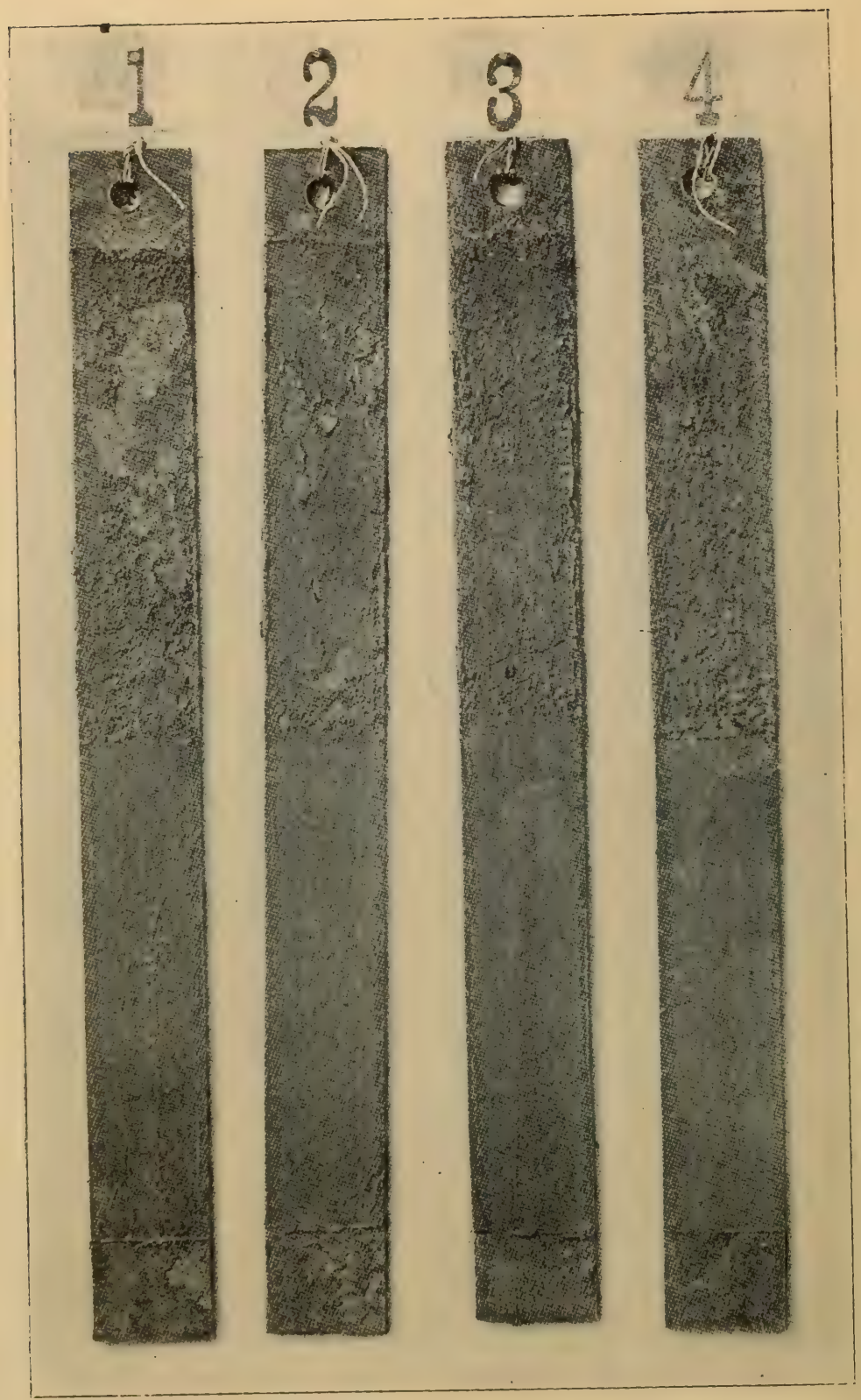
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* Read at the June, 1905, meeting of the American Association for Testing Materials. Abridged.

to preserve than new steel, rusty plates were substituted in all tests thereafter. And to still further endeavor to meet the existing conditions new plates were hung up and exposed to the smoke fumes until they became covered with sulphur scale, the thought being that an oxide scale due to atmospheric exposure might give different results. This scale or rust formation on these new plates apparently varied not only in amount, but also in the time of its formation, supposedly due to different chemical composition. As this might again give some variations in the experimental results, in order that all paints should be on as like footing as possible, angle bars eleven feet long were made use of, and as before hung in the smoke until rusted, then cleaned with wire brushes, each foot of the bar painted with a different paint and again hung up. The results, however, continued to be unsatisfactory.

In examinations of the test bars from time to time it was seen that upon many of them the paint was intact, but with protruding points which upon being pricked were found to be small rust formations, pushing up the paint from behind, clearly indicating that it was not the failure of the paints but the rust action on the inner surface that caused the damage. As no rust can form without the presence of moisture, and as all paints are pervious to moisture (as Dr. Dudley's careful investigations of the subject have proved) this led to the conclusion that it would be necessary in some way to tightly seal the surface. Many kinds of materials for doing this were tried, with as many different results, until three years ago it was decided that a cheap paraffin paper answered the purpose best of all, and since that time all experimentation has been along that line. The few test bars that have been brought along and exhibited indicate the results. Besides the experimental bars referred to, the paper covering has been tried in a small practical way against smoke action, and after two years and three months' exposure an examination of very recent date shows the outer paint, the paper and the first or adhesive coat all intact, and in many places where paper was removed for examination, the adhesive coat not yet dry and the surface of steel the same as when painted.

With such satisfactory results from this paper process in the smoke tests, it was concluded to make a large-scale application and severe test on a large number of eye-beams supporting



Experimental Bars exposed Eight Months, Lower One-Half Paper, Upper One-Half Paint, Three Coats

a floor over and within a few feet of salt water and upon which the rust was due not to smoke but to the almost continuous dampness and presence of sewer gases. This was done over a year ago and up to this time indication of damage of no kind is apparent.

The mode of application of the paper is as follows: After the rust is carefully cleaned off by means of stiff wire brushes, a certain kind of tacky paint is applied, the paper then covered over and tightly pressed upon the painted surface, the joints of the paper slightly lapping. As soon as the paper is in place, it is ready for the outside coat of paint. It will be observed that by this process, the first coat of paint, the paper and the coat of paint over the paper can be applied with one scaffolding, thereby greatly reducing the cost, especially in high and dangerous places.

These experiments, extending over only three years, are of too short a duration to determine the value of paper as a protection for iron and steel, but they certainly bring out the fact, at least in the case of smoke and gases, that the action begins from behind the paint and not from in front by the disintegration of the paint.

HIGH-SPEED TOOL STEELS *

By L. P. BRECKENRIDGE, Professor of Mechanical Engineering

Introduction

ONE of the most striking advances in recent years, from the point of view of the manufacturer, is the increase of the cutting speeds of machine tools and the consequent marked increase of the output of machine shops. Less than ten years ago cutting speeds ranged from 5 to 30 feet per minute; now speeds of 150 feet per minute are frequently employed. The first steps

* An engineering experiment station was established at the University of Illinois by action of the Board of Trustees, December 8, 1903. It is the purpose of the station to carry on investigations along various lines of engineering, and to study problems of importance to professional engineers and to manufacturing, railway, constructional, and industrial interests of the state. The laboratories of the College of Engineering are being equipped with additional apparatus and facilities to further such research work. It is believed that this experimental work will result

in this advance were taken by Messrs. Taylor and White at the Bethlehem Steel Works during the years 1898–1900, and the work of high-speed tool steels was first shown to the public at the Paris exhibition in 1900.

It cannot be doubted that the introduction of high-speed tool steels is destined to work radical changes in shop processes and to exert a marked influence on the cost of manufacturing.

Properties of Tool Steels

At the time of Taylor and White's first experiments Mushet and Jessop tool steels were in general use. These steels were of the self-hardening type. According to Mr. F. Reiser in an article on high-speed steel in "Stahl und Eisen," January 15, 1903, they had the following chemical composition:

Carbon	2.0%	Manganese	2.5%	Silicon	1.3%
Tungsten	5.0%	Chromium	0.5%		

The self-hardening property is called into play by the manganese, an alloy which favors the combining of the carbon with the iron. These steels were tempered simply by heating to a temperature of 1600° F. and then cooling in air. Mushet and Jessop tools, however, did not prove durable at high speeds, although they were far in advance of the ordinary carbon steels, and chromium was substituted for manganese with good results. The chromium steels required an entirely different treatment, as was found by Messrs. Taylor and White in their experiments at the Bethlehem Steel Works.

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in contributions of value to engineering science and that the presence of such investigations will give inspiration to students and add efficiency to the College of Engineering.

This Circular No. 1 is designed to furnish the engineers and manufacturers of Illinois some information regarding the recent advance in certain shop processes, — those involving the removal of metal. It will be followed by bulletins giving a complete account of a series of experiments and investigations now in process in the shops of the mechanical department.

Credit is due Mr. Henry B. Dirks, fellow in mechanical engineering, for collecting much of the information contained herein and for preparing the tables of results.

Copies of this circular may be obtained by addressing the Engineering Experiment Station, Urbana, Ill.

The exact chemical compositions of the new tool steels are secrets of the separate makers, and probably vary; however, it is known that the steels contain the following elements in varying quantities: carbon, tungsten, chromium, manganese, molybdenum and titanium. They usually run high in the per cent of alloy, the Taylor-White steel having as high as 12 per cent of tungsten and 4 per cent of chromium, while Böhler Bros.' Styrian steel, according to Mr. Reiser, has a maximum of 28 per cent of alloys. With this increase the carbon element has greatly decreased; most of it combines with tungsten, chromium and the other elements at high temperatures, remains in that state when cooled in an air blast and forms carbides of extreme hardness and durability at high temperatures. For best results of toughness and hardness these high-speed steels require for tempering a temperature of from 2000° to 2250° F., or a white heat bordering on the fusion point, and are then cooled in an air blast, lead bath or oil bath, according to the different makers. Mr. Reiser in his discussion has for this reason correctly named them " superheated steels."

Advantages of High-Speed Steels

High-speed steels, due to their hardness and durability at high temperatures, retain their edge when cutting at extremely high speeds, cases having been noted in which the tool worked at dark red heat without losing its edge. As can be seen from the tables, the speeds obtained are from three to four times those obtained with ordinary carbon steels. This, of course, means an increased output for a given shop and a consequent increase in the returns. This is not the only advantage of high-speed steel. It has been proved that such steel is more economical from the power standpoint, a given power removing a greater quantity of metal per unit of time at high speed than at slow speed. Of course the total power required is increased, but the increase is by no means proportional to the increase in the amount of work done.

There is, however, one condition that must be carefully considered before the introduction of high-speed steels in a shop. Machine tools constructed to use the old carbon steels are limited in capacity and will not stand the heavy stresses to which

they would be subjected if using high-speed steels at maximum speeds and feeds. This condition, however, is being met by the machine-tool builders, who are now designing and building especially heavy tools with powerful feed mechanisms with a view towards obtaining the highest possible efficiency of the steel used.

Proposed Investigations

While numerous investigations of tool steels have been made, there is still much to be done along the following lines: (1) Determination of the most economical speeds at various feeds and depths of cut for different materials and different sizes of tools. (2) Determination of the effect of different angles of rake and clearance on the power required to drive the tool. In order to obtain some of this information the Mechanical Engineering Department of the University of Illinois has installed an equiqment for testing high-speed steels. This consists of a Pratt and Whitney 15 inch by 7 feet 6 inch high-speed lathe of latest design, driven by a Westinghouse induction motor of $7\frac{1}{2}$ horse-power. The arrangement is such that fifty-six speeds can be obtained for any given diameter of work. The power required is measured by a Westinghouse portable polyphase wattmeter in circuit with the motor, so that readings can be taken at all times. Arrangements have been made for weighing all metal removed and for obtaining cutting speeds and feeds. An apparatus for tempering tools in an air blast has been set up and the angles of all tools will be accurately measured.

For the present, tests will be made on cast iron of various grades, a chemical analysis of each of which will be made. In the future other materials will be tried.

TABLE No. 1.

RESULTS OF EXPERIMENTS

MADE BY

MANCHESTER MUNICIPAL SCHOOL OF TECHNOLOGY, ENGLAND.

Reported by Dr. J. T. NICOLSON, Oct. 30, 1903.

Name of tool steel maker.	Material operated on.	Size of cut. Inches.	Cutting speed Ft. per min.	Material removed Lb. per min.	Duration of trial. Min.
Samuel Osborn & Co.	Soft C. I.	$\frac{3}{16}$ x $\frac{1}{16}$	84.7	3.175	20
T. Firth & Sons .	" "	$\frac{3}{8}$ x $\frac{1}{8}$	53.2	7.33	20
Samuel Buckley .	Medium C. I.	$\frac{3}{16}$ x $\frac{1}{16}$	49.0	1.73	20
" "	" "	$\frac{3}{8}$ x $\frac{1}{8}$	24.35	3.32	20
C. Cammell & Co.	Hard C. I.	$\frac{3}{16}$ x $\frac{1}{16}$	31.9	1.18	20
" "	" "	$\frac{3}{8}$ x $\frac{1}{8}$	18.1	2.54	20
Armstrong, Whitworth & Co.	Soft steel	$\frac{3}{16}$ x $\frac{1}{16}$	111.	4.14	20
" "	" "	$\frac{3}{8}$ x $\frac{1}{8}$	54.5	7.35	20
C. Cammell & Co.	Medium steel	$\frac{3}{16}$ x $\frac{1}{16}$	80.	3.17	20
Samuel Buckley	" "	$\frac{3}{8}$ x $\frac{1}{8}$	36.	5.30	20
" "	Hard steel	$\frac{3}{16}$ x $\frac{1}{16}$	41.2	1.71	20
C Cammell & Co.	" "	$\frac{3}{8}$ x $\frac{1}{8}$	20.	3.00	20

Reported in *London Engineering*, Oct. 30, 1903, and in *American Machinist*, Nov. 19 and 26, 1903. The tools in the above cases were all in good condition at the end of the trial. The experiments were made on cast iron and steel cylinders turned in a lathe furnished by Armstrong, Whitworth & Co.

TABLE No. 2.

RESULTS OF EXPERIMENTS

MADE BY

BÖHLER BROS. & CO., VIENNA AND BERLIN.

Reported by F. HEISSIG, Jan. 1, 1901.

Name of tool steel maker.	Material operated on.	Size of cut. Inches.	Cutting speed. Ft. per Min.	Material removed Lb. per min.	Duration of trial. Min.
Böhler Bros. & Co.	Cast Iron	$\frac{1}{8}$ X $\frac{1}{16}$	44.	.735	21
" " "	" "	$\frac{5}{16}$ X $\frac{5}{64}$	43.7	2.59	4
" " "	" "	$\frac{11}{64}$ X $\frac{5}{64}$	44.	1.69	6.5
" " "	" "	$\frac{11}{64}$ X $\frac{3}{32}$	29.4	1.14	30
" " "	" "	$\frac{9}{32}$ X $\frac{3}{32}$	45.9	3.86	4
" " "	"	$\frac{9}{32}$ X $\frac{3}{32}$	45.9	4.025	4
" " "	" "	$\frac{7}{32}$ X $\frac{1}{16}$	45.9	1.97	28
" " "	" "	$\frac{3}{32}$ X $\frac{1}{16}$	34.8	.882	15
" " "	" "	$\frac{1}{16}$ X $\frac{1}{16}$	45.2	.601	22
" " "	Cast Steel	$\frac{5}{32}$ X $\frac{1}{32}$	9.85	.203	114
" " "	Forged Steel	$\frac{5}{64}$ X $\frac{1}{8}$	98.65	.230	7
" " "	" "	$\frac{5}{32}$ X $\frac{1}{16}$	97.7	4.18	5
" " "	" "	$\frac{5}{64}$ X $\frac{1}{16}$	157.6	10.46	2
" " "	" "	$\frac{9}{64}$ X $\frac{1}{8}$	66.75	2.39	14
" " "	" "	$\frac{1}{8}$ X $\frac{1}{8}$	152.6	4.51	4.5
" " "	" "	$\frac{1}{8}$ X $\frac{1}{8}$	36.1	6.05	3.5
" " "	" "	$\frac{1}{16}$ X $\frac{1}{8}$	150.	7.06	3
" " "	" "	$\frac{15}{64}$ X $\frac{1}{8}$	53.5	1.29	8.5

Reported in *Stahl & Eisen*, Jan. 1, 1901. Böhler Bros. & Co. are represented in the United States by Houghton & Richards, Boston, Mass., and their steel is known as Styrian steel.

TABLE No. 3.

RESULTS OF DAILY WORK

AT

UNION PACIFIC RAILROAD SHOPS, OMAHA, NEBRASKA.

Reported by HENRY H. SUPLEE, July, 1903.

Name of tool steel	Machine tool used.	Material operated on.	Cutting speed. Ft. per min.	Size of cut. Inches.	Remarks.
Ati Novo	32-inch Pond lathe	Piston valve bushing Soft cast iron	74	$\frac{1}{2}$x$\frac{3}{32}$	
" "	" "	4" Piston rod No. 1 Scrap iron . .	18	$\frac{3}{4}$x$\frac{1}{16}$	
" "	27½-inch Pond lathe	Crank pin No. 1 Scrap iron . .	26	$\frac{1}{2}$x$\frac{1}{8}$	
" "	Niles vert. boring mill	Locomotive driver tyre Tyre steel .	40	$\frac{1}{8}$x$\frac{1}{8}$	Limit of belt on machine
" "	Bullard vert. boring mill	Piston head Cast iron . . .	20	$\frac{13}{32}$x$\frac{1}{8}$	
" "	Bement-Miles hor. cylinder boring mill	19-inch Cylinder. Cast iron (very hard) . .	18	$\frac{3}{8}$x$\frac{1}{8}$	Limit of motor
" "	88-inch Pond driver lathe	Driver tyre hardened by sliding on sand	24	$\frac{3}{8}$x$\frac{3}{32}$	Limit of machine
" "	30-foot Pond planer	Connecting rod. No. 1 Scrap iron . .	15	$\frac{9}{16}$x$\frac{1}{4}$	

Reported in the *Proceedings Institution of Mechanical Engineers*, July, 1903, and in *London Engineering*, July 31, 1903.

TABLE No. 4.

RESULTS OF EXPERIMENTS

MADE BY

BERLIN SECTION, VEREINES DEUTSCHER INGENIEURE,

Reported in their Proceedings, Sept. 28, 1901

Name of tool steel.	Material operated on.	Size of cut. Inches.	Cutting speed. Ft. per min.	Material remov'd Lb. per min	Duration of trial Min
Poldi-Schnell-dreher. .	Siemens-Martin Steel .	$\frac{3}{32}$X$\frac{1}{16}$	194	3.33	20
" "	" "	$\frac{11}{64}$X$\frac{1}{16}$	136	4.84	63
Böhler Rapid .	" "	$\frac{3}{16}$X$\frac{3}{32}$	126	5.92	95
" "	" "	$\frac{13}{64}$X$\frac{1}{8}$	45.2	3.21	113
Poldi-Diamant .	" "	$\frac{15}{64}$X$\frac{7}{64}$	35.5	2.64	140
Böhler Rapid .	" "	$\frac{1}{2}$X$\frac{3}{32}$	31.6	4.71	120
Böhler Titan-Boreas .	" "	$\frac{15}{32}$X$\frac{3}{64}$	17.4	1.43	120
Böhler Rapid	Cast Iron	$\frac{9}{64}$X$\frac{3}{16}$	72.9	7.39	59
Poldi-Diamant .	" "	$\frac{3}{16}$X$\frac{11}{64}$	50.3	5.21	61
Böhler Rapid . .	" "	$\frac{33}{64}$X$\frac{5}{32}$	47.3	14.43	120
Bergische-Stahl Industry	" "	$\frac{9}{16}$X$\frac{1}{16}$	37.4	4.61	120
Poldi-Diamant	" "	$\frac{33}{64}$X$\frac{9}{64}$	35.4	7.39	120
" "	" "	$\frac{5}{16}$X$\frac{9}{64}$	35.4	5.65	103
Bergische-Stahl Industry . .	" "	$\frac{33}{64}$X$\frac{5}{32}$	33.5	10.45	30
" "	" "	$\frac{25}{64}$X$\frac{3}{32}$	33.5	4.31	148
Poldi-Diamant .	" "	$\frac{7}{16}$X$\frac{7}{64}$	27.6	5.74	190
Böhler-Rapid	Cast Steel	$\frac{7}{32}$X$\frac{1}{16}$	47.3	2.45	120
" "	" "	$\frac{7}{32}$X$\frac{1}{16}$	33.5	1.45	120
Poldi-Diamant .	" "	$\frac{19}{32}$X$\frac{1}{32}$	31.55	2.34	100
Bergische-Stahl Industry . .	" "	$\frac{25}{64}$X$\frac{3}{64}$	26.6	2.15	120
" "	" "	$\frac{39}{64}$X$\frac{3}{64}$	19.71	2.15	120
Böhler-Rapid . . .	" "	$\frac{5}{8}$X$\frac{3}{64}$	17.73	2.11	120

TABLE No. 5.

RESULTS OF TESTS

MADE BEFORE

REPRESENTATIVES OF TECHNICAL PRESS AT BETHLEHEM, PA.,

August, 1900.

Name of tool steel.	Material operated on.	Size of cut. Inches.	Cutting speed. Ft. per min.	Duration of trial. Min.
Taylor-White . . .	Unusually hard tool steel	$\frac{3}{16} \times \frac{1}{16}$	15	15
Mushet	"	"	15	$\frac{3}{4}$
Taylor-White . .	Cast iron	"	50	20
Mushet	"	"	50	$1\frac{3}{4}$
Taylor-White . . .	Soft machine steel	"	150	15
Mushet	"	"	150	$\frac{1}{2}$

Reported in the *American Machinist*, August 16, 1900.

TABLE No. 6.

TABLE SHOWING INCREASE IN CUTTING-SPEED, ETC., AT BETHLEHEM STEEL CO., SINCE THE INTRODUCTION OF THE TAYLOR-WHITE PROCESS.

Average.	Oct. 25, 1898	May 11, 1899.	Jan. 15, 1900.	Gain in % cut of 3rd over 2nd.	Gain in % cut of 3rd over 1st.
Cutting speed .	8′-11″	21′-9″	25′-3″	16%	183%
Depth of cut . .	.23″	.278″	30″	8%	30%
Feed	.07″	.0657″	.087″	32%	24%
Lb metal removed per hour .	31.18	81.52	137.3	68%	340%

Average metal removed per hour per tool (round nose)=310 pounds in April, 1901, and has probably increased some since tnat time.

Reported in *American Machinist*, August 16, 1900.

TABLE No. 7.

RESULTS OF TRIALS

MADE BY

MESSRS. ARMSTRONG, WHITWORTH & CO., WITH TWIST DRILLS,

Reported by MR. J. GEDHILL, Dec. 4, 1903

Name of tool steel.	Material operated on.	Size of drill. Inches.	R. P. M. of drill.	Travel of drill. In. per min.	Duration.	Remarks.
"A. W."	Cast iron block 4" thick. . .	¾	525	13¼	Drilled several holes	Drill uninjured
"	"	¾	360	6	Drilled 137 holes	Not reground
"	"	1	240	4⅜	Drilled 76 holes	
"	Steel plate 2" thick	1	250	5	Drilled 150 holes	Required grinding
"	Steel gun cradle 5" thick	2	80	⅝	Drilled 124 holes	

Reported in *Engineering*, (London) December 4, 1903.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

ALUMINUM-ZINC ALLOYS. E. S. Shepherd. "Journal of Physical Chemistry," June, 1905. 4,000 w., illustrated. — Under the name of Alzine, and Sibley Casting Metal, aluminum-zinc alloys have been suggested for making castings for which pure aluminum is unsuited. They are said to expand on freezing, and to thereby yield sharper castings.

From his experiments, the author infers that this series of alloys presents no so-called definite compounds. There are two series of solid solutions, that of zinc in aluminum having a limiting concentration of about fifty per cent zinc, and that of aluminum in zinc of about four per cent aluminum, at the temperature of 217°. Below this temperature the reaction proceeds too slowly to permit of accurate determination, and it follows that the above concentrations are those which are present in the alloys as met in practice, and he finds his contention supported both by pyrometric and microscopic data.

The author further says: "In so far as we may predict them, the mechanical properties will not show any great difference between the cast and annealed alloys. This is due to the fact that the alloys apparently reach equilibrium readily, and any but very rapid chilling will allow the metal to come to equilibrium. Annealing increases the size of the crystals very greatly indeed and renders them more brittle. It is a fact well known to technical men, that these alloys become crystal-

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* Note. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

line under repeated shock, and break. It is for this reason that they have been largely displaced by the Al-Sn alloys, and are now used chiefly for ornamental castings, and for meter cases." **No. 406. C.**

Chain Making by Electric Welding. Andris-Jochams. "The Iron Age," July 13, 1905. 4,400 w., illustrated. — The author describes the application of electric welding to the manufacture of chains, a method patented by E. F. Giraud, of France. Claims for the Giraud process are economy, rapidity and superiority of production.

The author concludes as follows: "The chain-making industry in the United States represents an immense investment in improved machinery and processes. The average annual production of welded chain in this country is at least 50,000 tons. The adoption of the electric welding process would mean the dismantling of over 20 large modern chain shops and might result in the concentration of the production into fewer shops." **No. 407. B.**

The Growth of Large Gas Engines on the Continent. Rodolphe E. Mathot. A paper read before the Institution of Mechanical Engineers. 14,000 w., illustrated. — The author describes the principal types of large gas engines constructed on the Continent and the methods and principles of the makers. **No. 408.**

Cooling during Quenching of Steel. P. Lejeune. "Rev. de Métallurgie," April, 1905. 5,000 w., illustrated.— The author studied the cooling of steel during quenching by means of apparatus due to Le Chatelier, which acts somewhat similarly to that of Saladin. He finds that quenching in a small bulk of mercury, *e. g.*, as practiced for surgical instruments, is slower than in water. The maximum rate of cooling from the quenching temperature (about 850° C.) is indicated between 500° and 600°, but occurs at a much earlier stage in water and mercury quenching than with some other liquids; the thermo-couple, however, is embedded in the specimen. Using mixtures of water and glycerine, it was found that the duration of quenching varied in a somewhat similar way to the viscosity. The follow-

ing figures show this variation; the volume of liquid in each case is 2 liters: glycerine, per cent, by weight, 2, 10, 20, 50; relative viscosity (water = 1), 1.05, 1.13, 1.33, 1.6. The temperature fell from 700° to 100° in 6.5, 8.2, 10.3, 11.3 seconds respectively. The specific heat of the liquid affects the duration of cooling. Alcohol and xylol were used, and a comparison was also made between a bath of oil and one of equal viscosity consisting of 90 per cent glycerine in water; 27.5 and 11.3 seconds respectively were required for the fall of temperature from 700° to 150°. The shape of the cooling curves is affected by ebullition of the liquid and by the occurrence of a jacket of vapor about the specimen. The latter were in the form of cylinders of equal diameter, and the duration of quenching would seem to vary less rapidly than the length and more rapidly than the ratio of volume to surface. — Science Abstracts, July 26. **No. 409. C.**

Iron-Ore Deposits in Foreign Countries. "The Engineer," June 23, 1905. 1,800 w.—Analysis of a report of nearly 300 pages compiled at the board of trade (England) from a very large number of diplomatic and consular reports. **No. 410. B.**

16,000 Horse-Power Vertical Rolling-Mill Engines. "Engineering," June 23, 1905. 2,100 w., illustrated. — The article describes a powerful set of three-cylinder vertical reversing engines constructed for the Britannia Works of Messrs. Dorman, Long & Co., by Davy Brothers of Sheffield. They are believed to be the most powerful engines that have yet been built for the purpose. **No. 411. B.**

The Relative Economy of Blast-Furnace Gas Engines and Steam Engines in the Lorraine District. Dr. Ehrhardt. "Stahl und Eisen," June 1, 1905. 3,000 w. **No. 412. D.**

METALLURGICAL NOTES AND COMMENTS

Rossiter Worthington Raymond

Few engineers are more widely known than Dr. R. W. Raymond, the esteemed secretary of the American Institute of Mining Engineers, and the features of his photograph reproduced on our frontispiece will undoubtedly be familiar to most of our readers. The short outline we give below of his professional career testify to a useful, successful and therefore inspiring life. Through his high professional accomplishments and his attractive and gifted personality, Dr. Raymond has attained marked distinction as geologist and mining engineer, as writer and editor, as lecturer and presiding officer and more especially as secretary of one of the largest and most important engineering societies in the world, a position for which he possesses, in so remarkable a degree, the desirable qualifications.

Rossiter Worthington Raymond, Ph.D., was born April 27, 1840, at Cincinnati, Ohio. In 1852 he graduated from the Polytechnic Institute, Brooklyn, N. Y., and from 1858 to 1861 studied at the University of Heidelberg and Munich and at the Mining Academy of Freiberg, in Germany. From 1861 to 1864 he served as officer in the United States Army, and from 1864 to 1868 practiced in New York City as a consulting mining engineer and metallurgist. From 1868 to 1876 Dr. Raymond occupied the position of United States Commissioner of Mining Statistics for the states and territories in and west of the Rocky Mountains, his annual reports having been published by the government in eight octavo volumes. From 1870 to 1881 he was professor of economic geology at Lafayette College, Easton, Pa. Dr. Raymond was an original member of the American Institute of Mining Engineers, founded in 1871, and was that year elected vice-president of that society, while from 1872 to 1875 he served as president; from 1876 to 1877 again as vice-president; and, since 1884, by annual election he has been the secretary of the institute, editing the yearly volumes of "Transactions."

From 1867 to 1890 Dr. Raymond was editor of "The Engineering and Mining Journal" of New York (called for the first two years of that period "The American Journal of Mining"). In 1873 he was United States commissioner to the Vienna International Exposition. From 1875 to 1895 he was consulting engineer of the firm of Cooper & Hewitt, iron and steel manufacturers, and for the greater part of that time acted as an assistant of Hon. Abram S. Hewitt in the Cooper Union, of which he directed the free popular scientific evening lectures until it was assumed by the board of education. From 1885 to 1889 he was one of the New York State electric subway commissioners for the city of Brooklyn, whose final report, written by him, was widely republished as the best statement of the problem of municipal electrical engineering as it then existed.

Dr. Raymond is a member of the New York State and of the federal bar, practicing chiefly in the departments of mining and patent law. His essays on mining law are quoted as authority. In 1904 he was lecturer on mining law in the Law School and Mining School of Columbia University.

He is an honorary member of the Society of Civil Engineers of France, the Iron and Steel Institute, and the Institution of Mining and Metallurgy of Great Britain, the American Philosophical Society and other scientific bodies.

Outside of his professional work, Dr. Raymond has published several volumes of stories, notes of travel, criticism, etc., and numerous biographical sketches of distinguished men personally known to him, including Alexander L. Holley, Peter Cooper, Abram S. Hewitt, Eckley B. Coxe and many European technical authors and teachers.

Iron and Steel Institute

The autumn meeting of the Iron and Steel Institute will be held at Sheffield on September 26, 27 and 28, 1905. The following papers have been offered for reading:

1. "The Metallurgical Department of Sheffield University," by Prof. J. O. Arnold (Sheffield).

2. "The Thermal Transformation of Carbon Steels," by Prof. J. O. Arnold and A. McWilliam (Sheffield).

3. "The Nature of Troostite," by Dr. Carl Benedicks (Upsala).

4. "The Occurrence of Copper, Cobalt and Nickel in American Pig Irons," by Prof. E. D. Campbell (Ann Arbor, Mich.).

5. "Pipe in Steel Ingots," by J. E. Fletcher (Sheffield).

6. "Steel for Motor-Car Construction," by L. Guillet (Paris).

7. "The Presence of Greenish-Colored Markings in the Fractured Surface of Test Pieces," by Capt. H. G. Howorth, R.A. (Sheffield).

8. "Over-Heated Steel," by Arthur W. Richards (Grangetown) and J. E. Stead, F.R.S. (member of Council).

9. "Segregation in Steel Ingots," by B. Talbot (Middlesbrough).

10. "A Manipulator for Steel Bars," by Douglas Upton (Jarrow).

11. "Machinery for Breaking Pig Iron," by Cecil Walton (Whitehaven).

12. "The Influence of Carbon on Nickel and Iron," by George B. Waterhouse (New York).

The Mining and Metallurgical Congress at Liège

The following papers were read before the metallurgical section of the Congress recently held at Liége, Belgium, in connection with the International Exposition now being held in that city.

"The Use of Poor Caking Coals for Coke-Making," by M. Hennebutte.

"The Cleaning of Blast-Furnace Gas," by M. Bain.

"The Influence of Titanium on Pig Iron and Steel," by M. Delville.

"The Manufacture of Cement from Blast-Furnace Slag," by the Chevalier Cecil de Schwarz.

"The Employment of Blast-Furnace Slag for Portland-Cement Manufacture," by Dr. H. Wedding.

"Review of the New Methods of Making Steel in Open-Hearth Furnaces," by P. Ackers.

"Special Steels," by M. Guillet.

"Methods of Preventing Piping in Steel Ingots," by M. Daelen.

"Effect of Liquid-Air Temperatures on the Properties of Iron and Its Alloys," by Mr. R. A. Hadfield.

"The Shearing and Cutting of Metals by Oxygen," by M. Jottrand.

"Double Tempering for Large Steel Forgings."

"The Microscope in Metallurgy," by M. Le Chatelier.

"The Electric Smelting of Steel," by M. Gin.

"The Electric Furnace in Metallurgy," by M. Pitaval.

"The Cermak-Spirek Furnace for Roasting and Calcining Minerals," by M. Spirek.

Two of these papers will be found reproduced in the present issue of *The Iron and Steel Magazine*, while the others will be printed in subsequent numbers.

The Chemist and His Work. — One of the most important assistants to the metallurgist is, without doubt, the chemist, who may well be called his aide-de-camp. The results received from him are now taken so much as a matter of course that it is almost impossible to believe that but little more than twenty years ago the laboratory, if it existed at all, was surrounded with mystery. A "full" analysis of a specimen of steel was then spoken of with bated breath, and its accuracy was doubtful.

When one peruses a work on metallurgy of even so late a date as a hundred years ago, the extraordinary designations and terms employed seem to indicate that metallurgy was regarded as a branch of cabalistic art. Certainly before the year 1750, or about that date, the art of metallurgy outside the production of the simplest products seems almost to have been classed with witchcraft and sorcery.

Past metallurgical literature shows how impossible it was for the workers in those days to advance until the alchemist passed away and the chemist appeared on the scene. It has, therefore, been largely due to the chemist that the Egyptian darkness prevailing so long in the world's history has been cleared away, thus making the first real progress in our era possible. All honor to the noble little band of chemists who led the way to that better state of things from which metallurgy in due time received its share of the progressive benefits resulting from their work! They came largely from Sweden towards the middle and the end of the eighteenth century,

whilst later, those of Germany, France and England joined in the good work.

A modern metallurgical chemist has to take a wide range of view. He must not only be well gifted in the art of the laboratory at large, but must keep an intelligent eye upon the many ramifications of his special branch. After showing that the raw materials which pass under his notice are satisfactory, he may for a time lose touch with the actual manufacturing processes, but the final product must come under his hands again. Unlike the mechanical engineer, whose work is more or less finished with the completion of his contract, it is to the chemist the metallurgist has often to turn, long after the product has been in use, to show whether his work has resulted in failure or success.

It is, therefore, a matter of no little anxiety for the chemist to certify that the products placed before him are satisfactory; for great as have been the advances in laboratory analytical methods, we are yearly finding that as products become more complex so must our laboratory respond to the call made upon it and rise to meet conditions involving difficulties of no mean order.

The laboratory is often considered to be a mere recording instrument; but it is far more than that. There are problems in steel manufacture awaiting solution which can only be solved by the chemist; but his methods, although they are aided by microscopy, are still far from perfect. Take one example alone,— that of the correct determination of the various forms of carbon in steel. For many purposes we want far more than a mere laboratory report of the percentage of carbon present in a specimen — that is much less than half the knowledge we need. We must know in what forms the carbon exists. Abel, Arnold, Blair, Brinell, Campbell, Campredon, Jüptner, Ledebur, Edward, Riley and Stead have done great work in this direction. The complex combinations now met with in alloys or special steels will be appreciated when it is remembered that there are often more than ten different and important elements in a single alloy combination. This will give some idea of the difficulties to be encountered. It is thus found that our present methods are not too reliable, and there is room for much more light in this direction.

The subject is of such importance that if a special committee were formed to take up this matter it might do great service to the world at large whilst benefiting the metallurgist more directly. Such information would enable us to secure, unerringly, important practical results that are now obtained in far too haphazard a manner. We have at present no means of properly determining these combinations by the method which should be the simplest, best and most trustworthy, — that is, chemical analysis. Mysterious failures still occur, and one of the helps to solve this problem will be to know the full why and wherefore of the exact composition of our steel. It is for these reasons, amongst others, that I place the responsibility of the metallurgical chemist so high. When once he recognizes what is needed from him, he will, we may be sure, rise to meet the want, as he has done in the past. Since the great work of Abel and Ledebur there has been too great a lull in the demands we have made upon the chemist. We have been content to accept his results as a mere laboratory return of the percentages of certain elements, often not recognizing that the various complex combinations of carbon are of vital importance.

Excellent work is now being undertaken conjointly by Dr. R. T. Glazebrook, F.R.S., of the National Physical Laboratory, and Mr. H. Le Chatelier in their researches " On the Constituents of Steel." The first object of this investigation is to find the conditions under which quenching for hardening steel should be carried out, with a view to determine the nature and character of the various micro-structures of steel as ordinarily accepted. Although these at present are purely theoretical, no doubt discussion will render excellent service in enabling investigators to understand the different structures of steel obtained by heat treatment.

In America a movement is in progress for improving and systematizing chemical analysis. It is proposed that the National Bureau of Standards at Washington should take up this work. An influential committee has been formed, including, amongst others, Dr. C. B. Dudley. The following procedure has been recommended:

(1) To impress on chemists the necessity, by using new methods and pure materials, of arriving at greater uniformity.

(2) To try to discover to what the present lack of uniformity is due.

(3) To test, in coöperation with the National Bureau of Standards, various methods to see if they are suitable for general use.

(4) To prepare samples of different character, the composition of which is known exactly.

(5) To distribute such samples to persons wishing to test the accuracy of their methods of analysis. From R. A. Hadfield's Presidential Address, Iron and Steel Institute, May, 1905.

The Knoth Slag Process for Manufacturing Steel. — On May 2, 1905, letters patent were issued to Henry Knoth, formerly superintendent of the steel plant of the Tennessee Coal, Iron and Railroad Company, at Ensley, Ala., and now superintendent of the Monterey Steel Plant, at Monterey, Mexico, for a process which has proved successful in increasing the output of steel while reducing the cost of production. Mr. Knoth, who has given considerable study to the manufacture of basic open-hearth steel, reached the conclusion that the present method of manufacturing steel could be greatly improved if a liquid basic slag could be provided at a minimum expense to start the heat quickly into action. When the molten slag is tapped from an open-hearth steel furnace and thrown away there is a loss not only of considerable basic materials but also of the heat in the slag. Obviously, if this heat and these basic properties can be successfuly utilized in purifying other heats an economy in manufacture will result. According to the Knoth slag process the liquid slag resulting from an initial heat, prepared in the usual manner in a basic open-hearth furnace, is used continually to purify subsequent heats by being returned to the same furnace, unless it is stopped for considerable repairs, and in that event to any other furnace then ready for it. The losses in the basic properties of the slag by continually purifying heats are replaced by lime or other desirable fluxing materials.

Preferably the unpurified metal to be acted upon by the molten slag is introduced into the furnace in a molten condition, or, better, is first blown in an acid converter. In both cases the reactions will at once set in in the bath, since the slag is in a ready condition. The duration of the heat is thereby considerably

reduced. This process is being used at the Monterey Steel Plant, where it has uniformly given excellent results. Thus, 24 tons of pig iron were melted with 6 tons of scrap without additions and tapped with 1 per cent carbon into an open-hearth furnace. The slag from a previous heat in this furnace was returned thereto in liquid condition with about 1,000 kg. of limestone. The liquid slag immediately acted on the limestone, and after the addition of some fluorspar the reaction began at once. After adding ore several times the heat was tapped in two hours and thirty-five minutes. This process was repeated a number of times with substantially similar results. Below are the analyses of the unpurified metal, the slag and the steel as tapped in three succeeding heats, the times for the heat being given.

DURATION OF THE HEAT FROM CHARGING OF THE LIQUID MATERIAL TILL TAPPING

No. 1	No. 2	No. 3
2 hours 35 minutes	2 hours 40 minutes	2 hours 5 minutes

ANALYSIS OF UNPURIFIED METAL CHARGED

	No. 1 Per cent	No. 2 Per cent	No. 3 Per cent
Silicon	Trace	Trace	Trace
Manganese	0.14	0.16	0.15
Phosphorus	0.115	0.121	0.130
Sulphur	0.061	0.065	0.064
Carbon	1.05	0.96	0.89

ANALYSIS OF THE SLAG

	No. 1 Per cent	No. 2 Per cent	No. 3 Per cent
SiO_2	12.96	12.77	11.76
Al_2O_3	7.89	8.11	7.93
Fe	15.40	11.48	14.39
CaO	48.47	47.50	44.79
MgO	6.62	7.28	8.51
MnO	2.00	2.38	2.95
S	0.38	0.45	0.46
P_2O_5	1.80	2.96	4.35

ANALYSIS OF THE STEEL

	No. 1 Per cent	No. 2 Per cent	No. 3 Per cent
Manganese	0.38	0.32	0.45
Phosphorus	0.01	0.006	0.012
Sulphur	0.045	0.038	0.049
Carbon	0.10	0.09	0.23

These analyses are furnished by Franz Putsch, chief chemist of the Monterey Steel Company.

The process will operate most successfully when the pig metal is treated in an acid converter, and it is clear from the results above obtained that where the unpurified metal is blown in the converter to 1 per cent carbon and then charged in the open-hearth furnace and treated in accordance with the Knoth slag process a production of 200 tons of steel within twenty-four hours can be easily obtained from a 30-ton furnace.

The Knoth process will be of considerable importance to Southern steel manufacturers. It is believed that the saving in basic materials largely offsets the cost of blowing the metal in a converter and would cheapen the duplex process, such as is now being successfully carried out at the Ensley steel plant. In addition to this the other advantages of the process consist in the increase of production, the short time of the heats in the furnace and a correspondingly increased life of the furnace hearth, the opportunity to repair the furnace bottom between heats without interrupting the continuity of the process, the utilization of all the basic properties in the slag and the reduction of the quantity of material thrown on the slag pile and handled at an expense. "The Iron Age," July 13, 1905.

The Iron Pillar at Delhi. — When one goes to India he is apt to have his ideas of modern achievement and civilization considerably changed. Americans usually think they are the only ones who know how to produce large forgings, and yet on the plains of Delhi, the ancient capital of India, near the Kutub Minar, stands an immense iron pillar which is the most curious antiquity of all India. It is a wonderfully fine forging, 50 feet long and 16 inches in diameter. It rises 22 feet above ground — the remainder is below ground. There are several weird legends connected with its history, and its exact date is unknown, but it is certain that it extends back into the past to a date before our boasted Western civilization even had a beginning. It records its own history in Sanskirt in a deeply cut inscription on its face, and students assign the third or fourth century after Christ as the date of this inscription. The Colossus of Rhodes and the statues of Buddha described by Hiown Thsang, the old Chinese traveler, were of brass or copper, hollow,

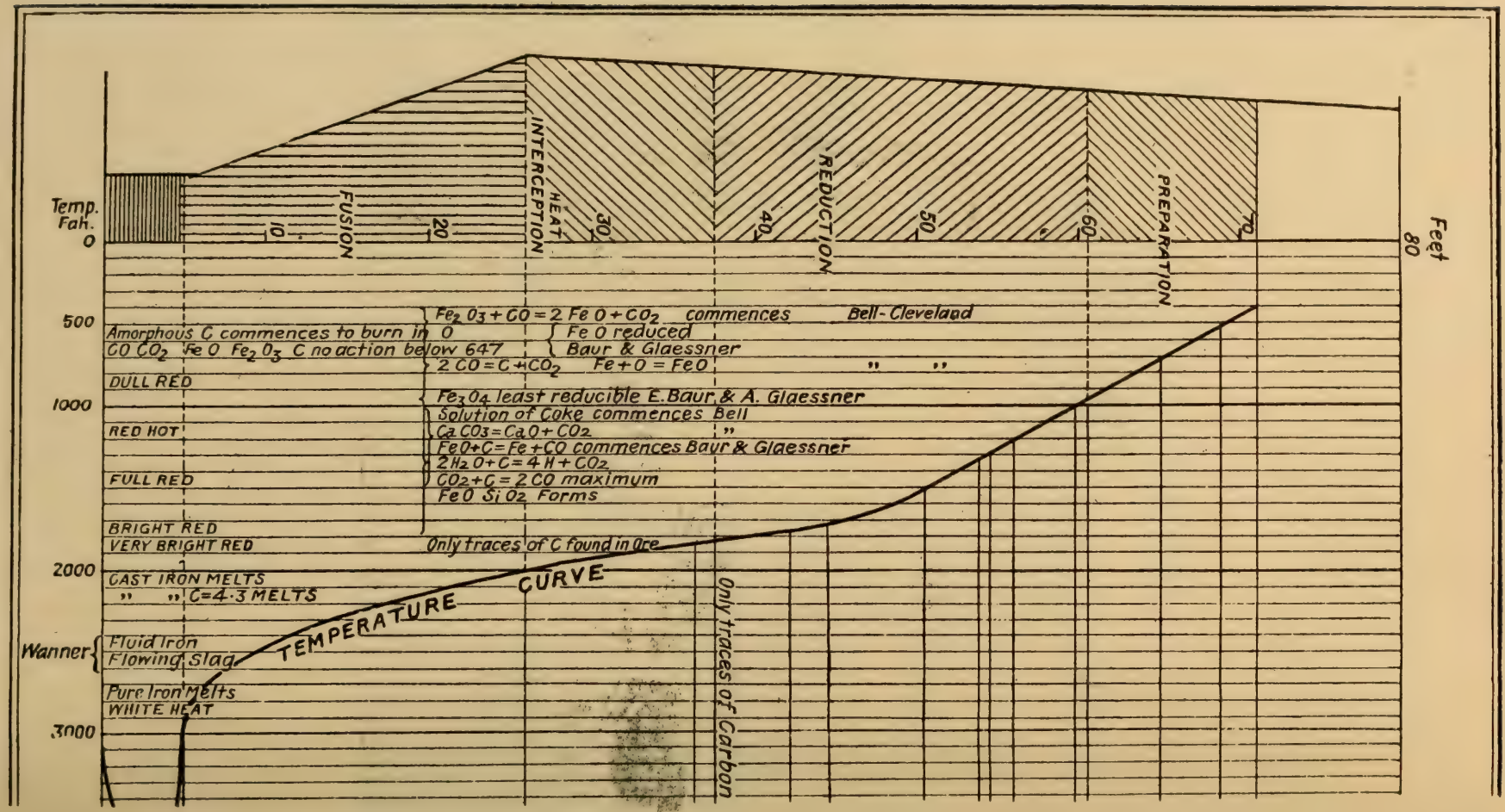
and of pieces riveted together, but this "Pillar of Fame" is a solid shaft of wrought iron.

In one of the temples of India there are some iron beams supporting a portion of the building which are almost as remarkable forgings as the pillar itself, and probably as old. These



Iron Pillar of Delhi, with Arch of Kutub to the Right

beams are about twice as deep in the center as at the ends, showing that the people of that remote age understood how to distribute the material in the beams to the best advantage. It is exceedingly interesting to know that these great forgings which were made over fifteen hundred years ago still stand as a monument to the ancient industries of India.


Temp. Fah.
0
500
1000
2000
3000
Feet
80
10
20
30
40
50
60
70
FUSION
INTERCEPTION
HEAT
REDUCTION
PREPARATION
Fe2 O3 + CO = 2 Fe O + CO2 commences Bell-Cleveland
Amorphous C commences to burn in O
CO CO2 Fe O Fe2 O3 C no action below 647
Fe O reduced
Baur & Glaessner
2 CO = C + CO2 Fe + O = Fe O " "
DULL RED
Fe3 O4 least reducible E. Baur & A. Glaessner
Solution of Coke commences Bell
RED HOT
Ca CO3 = Ca O + CO2 "
Fe O + C = Fe + CO commences Baur & Glaessner
2 H2 O + C = 4 H + CO2
FULL RED
CO2 + C = 2 CO maximum
Fe O Si O2 Forms
BRIGHT RED
VERY BRIGHT RED
Only traces of C found in Ore
CAST IRON MELTS
" " C=4·3 MELTS
TEMPERATURE CURVE
Only traces of Carbon
Wanner
Fluid Iron
Flowing Slag
Pure Iron Melts
WHITE HEAT

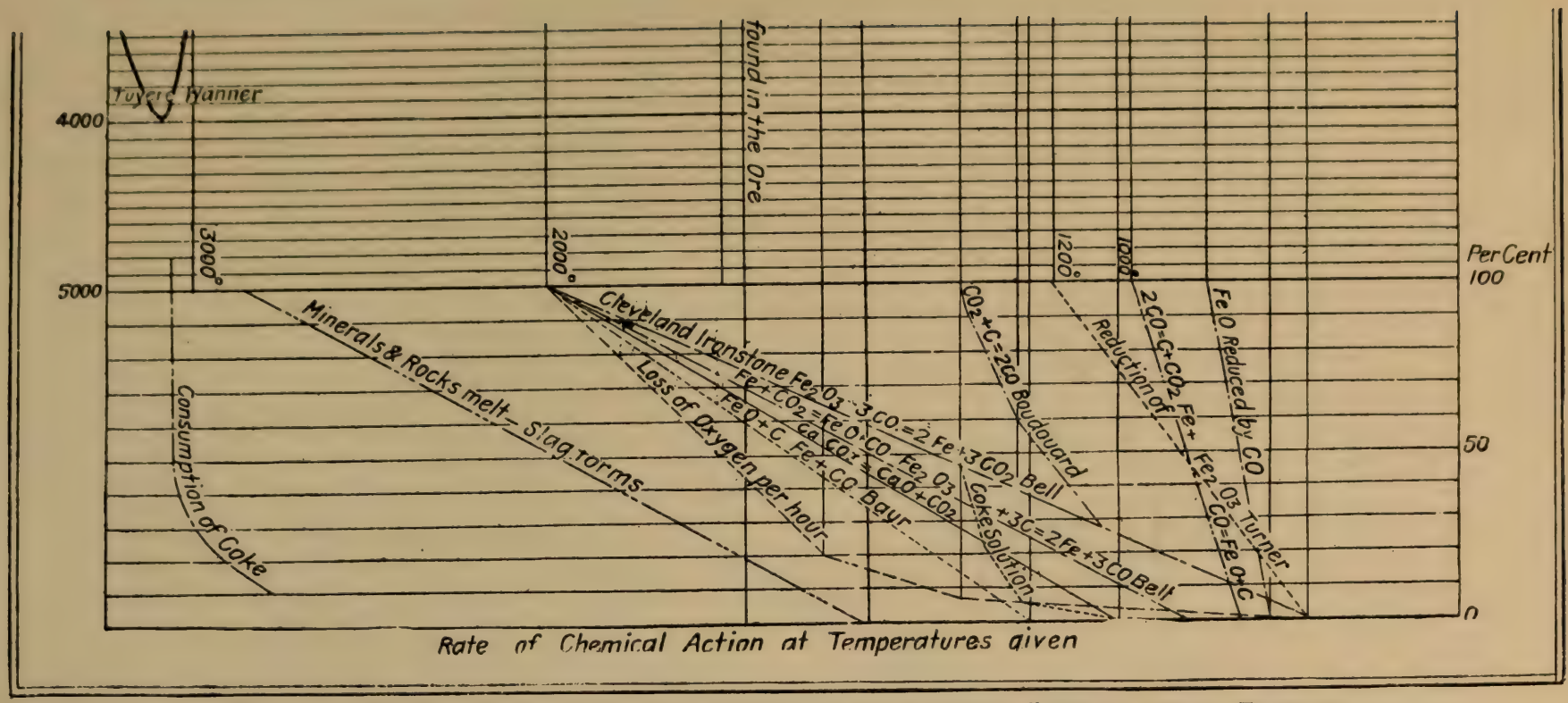


DIAGRAM OF TEMPERATURES AND CHEMICAL CHANGES IN THE DIFFERENT ZONES OF A BLAST FURNACE.

India boasts of exceedingly rich deposits of iron, but unfortunately the iron ore and flux are widely separated and the coal is so high in ash that it has not been possible to work deposits by modern methods. The most primitive furnaces were probably short shaft, built in the underwind side of a hill, the wind furnishing the blast. Charcoal was used as fuel and the ores reduced in small quantities. The thick masses of iron were raked out of the bottom of the furnace and forged into shape so that they could subsequently be welded into large masses if required. Later the furnaces were equipped with bellows, and their height greatly increased until it reached about 10 feet, and the output was greater than that of any other primitive iron-making furnace. It is interesting to know that cast iron was probably first made in these furnaces of ancient India, but it was made as the result of an accident and was always thrown away with the slag. When the draught became especially good and the furnace was very hot it would sometimes make a few hundred pounds of cast iron, which would run out of the slag and be thrown away. These tall furnaces are still used in some remote districts of the Himalayas, but they are fast being displaced by iron and steel products imported from Europe and America.

The iron pillar at Delhi has always been bright, and some writers attribute this to the fact that certain of the pilgrims divined this pillar as a part of their religious observances, and claim that the grease and oil applied to it in this way protected it; but it is probably true that the surface is covered with a black oxide rust which has protected it from further oxidation. Several attempts have been made to obtain a sample of the iron for analysis, but as the natives regard the pillar with superstitious awe, no complete analysis of the material has been made.

Wondrous does this tale of a past civilization become when one remembers that it has been only in late years that any modern nation has been able to create anything like so massive a pillar of wrought iron. "Iron Trade Review," July 6, 1905.

Blast-Furnace Practice. — The practical application of the pyrometer to the determination of the temperatures of the zones of chemical changes which are found to exist in the blast

furnace has enabled the author to prepare the accompanying diagram (pages 260 and 261).

The *temperature curve* shows the gradual increase in temperature of the materials of the charge as they descend in the furnace through the different zones. The chemical changes are clearly indicated by the portion of the diagram marked in percentages. Increasing or decreasing the height of the furnace would not greatly modify the diagram, while changes in the diameter would affect the time during which the materials take to pass through the zones. It will be noticed that the temperature line in the neighborhood of the boshes very nearly coincides with the angle of the brickwork, *i. e.*, about 70°.

In regard to the formation of slag, it will be obvious that this can only proceed as the combining materials intermingle in close contact, and reach a part of the furnace where the temperature is sufficiently high. A reference to the diagram will explain the reason why the quality of the iron is affected by allowing the stock to fall too low in the furnace; the temperatures in the heat interception and fusion zones would remain constant, but the volumes of the zones of preparation and reduction would be considerably curtailed. Horace Allen, in "Iron and Coal Trades Review," July 7, 1905.

Percentage of Iron and Steel and Other Leading Products of the United States Steel Corporation and Independent Producers in 1902, 1903 and 1904. — In the following table we compile from our Annual Report for 1904 the percentage of the total shipments of iron ore from the Lake Superior region by the United States Steel Corporation in the calendar years 1902, 1903 and 1904, as compared with the shipments of iron ore from the same region by all other companies, firms and individuals; also the percentage of the total production of iron ore, coke, pig iron, steel ingots and castings, all kinds of finished rolled iron and steel and wire nails by the corporation and by all independent producers for the same years.

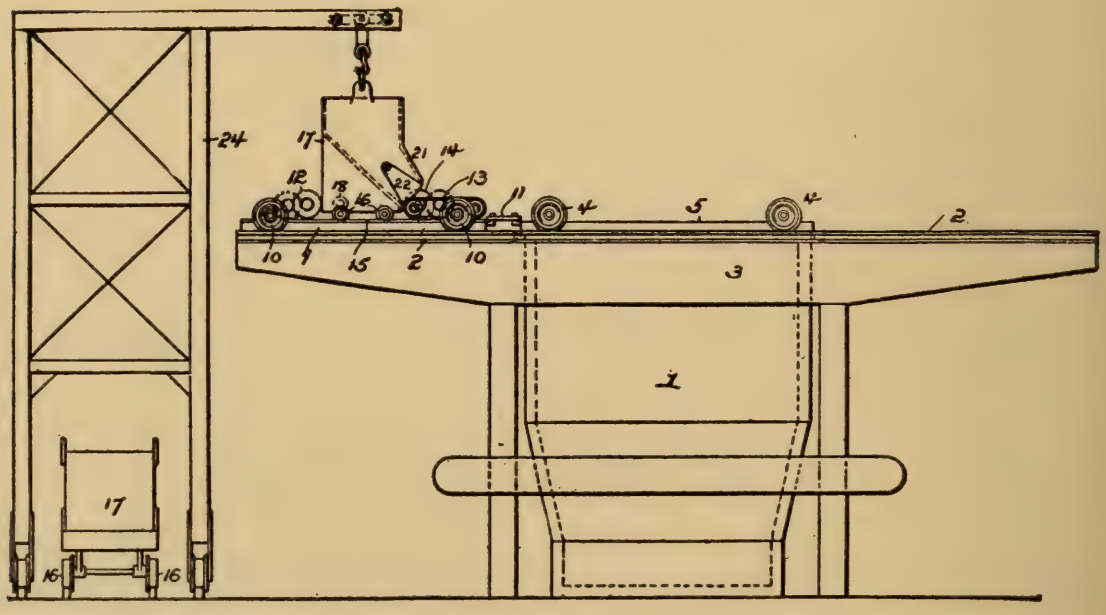
The percentage of shipments and production by the United States Steel Corporation and by independent producers.	1902		1903		1904	
	U. S. S. Corp.	Independents	U. S. S Corp.	Independents	U. S. S. Corp.	Independents
Shipments of iron ore from Lake Superior	60 4	39.6	58.8	41.2	53.8	46.2
Total production of iron ore,	45.1	54.9	43.8	56.2	38.0	62.0
Production of coke	37.4	62.6	34.2	65.8	36.6	63.4
Bessemer, basic, forge, foundry and all other pig iron,	44.3	55.7	39.9	60.1	44.3	55.7
Spiegeleisen, ferro-manganese, and ferro-phosphorus	81.0	19.0	81.0	19.0	70.5	29.5
Total pig iron, including spiegeleisen, etc.	44.7	55.3	40.4	59.6	44.6	55.4
Bessemer steel ingots and castings	73.9	26.1	72.0	28.0	69.0	31.0
Open-hearth steel ingots and castings	52.4	47.6	51.0	49.0	50.4	49.6
Total steel ingots and castings	65.7	34.3	63.5	36.5	61.0	39.0
Bessemer steel rails	65.4	34.6	65.6	34.4	57.2	42.8
Structural shapes	57.9	42.1	60.3	39.7	55.1	44.9
Plates and sheets, excluding nail plate	59.4	40.6	59.9	40.1	58.0	42.0
Wire rods	71.5	28.5	73.1	26.9	71 3	28.7
Bars, skelp, nail plate, open-hearth and iron rails, etc.	31.1	68.9	29.8	70.2	28.6	71.4
Total of all finished rolled products	50.8	49.2	51 2	48.8	47.8	52.2
Wire nails	64 8	35.2	70.6	29.4	67.0	33.0

In the three years covered by the table the percentage of the production of iron ore by the United States Steel Corporation fell from 45.1 per cent in 1902 to 43.8 per cent in 1903 and to 38 per cent in 1904. The decrease in 1904 was due principally to the large stock of iron ore which had been carried over from

1903. So also was the decrease in the shipments of iron ore in 1904. The corporation's percentage of the production of pig iron was about the same in 1904 as in 1902. The corporation was a large buyer of pig iron in the three years under review, its furnace capacity not being equal to its converting and finishing capacity. In steel ingots and castings a decrease of 4.7 per cent is shown in 1904 as compared with 1902. Bessemer steel rails show a decline from 65.4 per cent in 1902 to 57.2 per cent in 1904, the decrease in the latter year being caused mainly by the competition of the Lackawanna Steel Company (independent), which was an active competitor for Bessemer rails in 1904, which it could not be in 1902 and during the greater part of 1903, while building its new plant. The increased competition of open-hearth steel rails in the South was also a factor. All kinds of finished rolled iron and steel, including rails, show a decrease of 3 per cent in the period covered by the table, although wire nails show an increase of 2.2 per cent in 1904 as compared with 1902. In structural steel the corporation lost nearly three points in 1904 as compared with 1902. In wire rods and plates and sheets there were slight losses by the corporation in 1904 as compared with 1902. "The Bulletin," American Iron and Steel Association, July 15, 1905.

Blast-Furnace Filling Apparatus. — John W. Seaver, assignor to Wellman-Seaver-Morgan Company, Cleveland, Ohio, has patented (U. S. 792,735) the method of charging furnaces here outlined, which is valuable principally because of its flexibility, and because the ore may be run in at any convenient level below or above the furnace top. A combination of two traveling covers is placed over the furnace, the edges of the covers extending down into troughs to form a water seal, and a traveling lorry being arranged to run over the auxiliary cover, which is normally out of use. Among the several ways in which the apparatus may be employed in a plant is the one shown in the drawing. Here the ore is run in on the lorry (17) on the ground level, and then hoisted (by any convenient means, not shown) to a position on the traveling crane at the left of the drawing. At the point in the illustration the lorry (17), shown now in side view, is moved by its motor (18) along the track (15), so that its discharge nozzle (21) projects over the endless conveyor (13). The motor (12)

moves auxiliary cover (9), pushing the cover (5) in advance, the depending edges being then raised out of the water-seal trough. As the covers move, the conveyor apron (13) conveys the charge from the lorry to the end of the auxiliary cover and dumps it between the covers into the furnace (1). The covers may be moved back and forth at any convienent speed to distribute the charge as desired. By extending the lorry's track, several kinds of ore may be received from different points and separately weighed by passing over scale-beams. If it is desired to deposit the coke on the edges of the furnace the lorry can be provided with side partitions for the coke, the ore being carried in the center. "Engineering and Mining Journal," July 22, 1905.



The Invention of Grooved Rolls. — The "Iron and Coal Trades Review" publishes the following letter:

"Whilst abroad in March I observed a statement in the 'Times' that a monument of Henry Cort has been raised, with an inscription which added to his well-known claim to be the inventor of puddling that of being the inventor of grooved rolls. The inclosed abstract from a very interesting paper, entitled 'How to Beat the Dutch without Fighting,' by Sir William H. Bailey, of Manchester, on two volumes by Andrew Yarranton, written in the year 1676, entitled 'England's Improvement by Sea and Land. To out-do the Dutch without Fighting; to Pay Debts without Moneys,' reads as follows.

"'He (Yarranton) says: "I have noticed the way in which rings and bolts are made for ships, and we ought to imitate in this country what they do in Germany, for I have seen bars of iron made perfectly round, about 12 feet in length and 1 inch diameter, and they are sent down the river to Holland, where they are employed for making bolts and rings. They are uniform in size, and are much better for use in shipping than those which are made with the hammer." It appears these were made with an engine truly made for the purpose, and he suggested that such a machine should be introduced into this country. That is a common rolling mill, and it shows how far we were behind in iron manufacture in his time when that was an unknown tool in this country.'

"It would be interesting to know if any of your readers can throw further light on this subject, as it is clear that bars 12 feet long and 1 inch diameter, perfectly round, could not have been made or rolled other than in grooved rolls.

"FRED MILLS.

"Ebbw Vale, May 22, 1905."

James M. Swank in the "Bulletin" of the American Iron and Steel Association comments on the letter as follows:

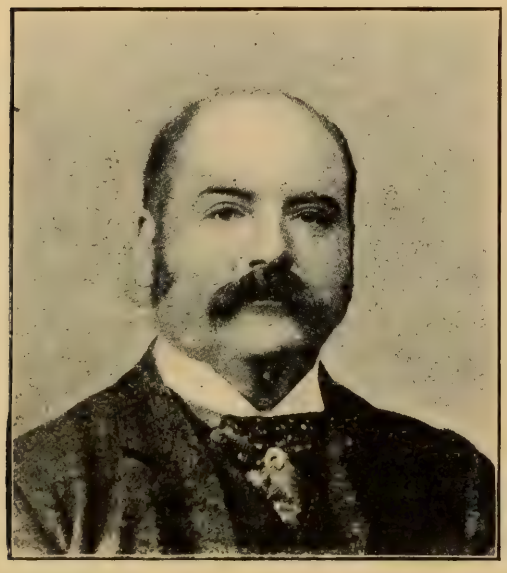
"In Chapter 8 of 'Iron in All Ages' will be found much interesting information concerning the use of the rolling mill prior to Cort's time. Cort's great invention was the puddling furnace, not the rolling mill, but he is entitled to the credit of having improved and enlarged the uses of the latter." "Iron Trade Review," July 6, 1905.

Electric Furnace for Research Work at High Temperatures.—Dr. Harker has invented a form of electric furnace in which small samples of metal can be heated to temperatures of 2200° C. without coming into contact with carbon or any noxious gases. The conductor conveying the electric current is a tube of similar composition as the filament of a Nernst lamp. For many purposes the usefulness and life of a furnace constructed in this way may be much increased by adopting a "cascade" system of heating; that is, the energy supplied may be divided, so that only sufficient is put through the tubular conductor to raise its temperature, say, 1000° C. above its surroundings, the sur-

roundings being maintained at 1000° C., thus enabling a temperature of 2000° C. to be attained in the tube without straining it unduly. The regulation of temperature in small furnaces of this type is so perfectly under control that very well defined melting-points may be taken with very small quantities of substance. The thermo-electric method has been used in these furnaces for determining the melting-point of platinum, the mean result of the experiments giving 1710° C. ± 5° C. "Technics," July, 1905.

William Jessop

We regret to announce the death of Mr. William Jessop, of Thornsett Lodge, Bradfield, which took place at his residence, after a very long illness, on Tuesday. The deceased gentleman was well known as the chairman of William Jessop & Sons, Limited, steel manufacturers, of Brightside, Sheffield. Mr. Jessop, who was only forty-eight years of age, was a son of the late Mr. Thomas Jessop, who was largely responsible for the building up of the great business at Sheffield. It was founded by a previous generation of the family but made its most rapid development during the time it was controlled by Mr. Thomas Jessop, who was a man of great resource and public spirit. He was master cutler in 1863, and mayor of Sheffield in 1863–1864. Mr. William Jessop was educated at the Collegiate School, Sheffield, and afterwards at Repton. From Repton he went to Germany, and eventually completed his education at Cambridge University. He did not, during the greater part of his life, take a very active part in the business at Brightside, although nominally he was concerned with the firm, and from 1880 had occupied the position of a director. On the death of his father, in 1887, he became chairman of the company, and remained so until the time of his death. In addition to his directorship of William Jessop & Sons,



he was also for a considerable period a director of the Sheffield and Rotherham Bank, and a director of the Yorkshire Engine Company. Mr. Jessop's only son, Mr. Thomas Jessop, entered the business so recently as a month ago, after completing his education. It is interesting to note that the business of William Jessop & Sons has existed under its present title since 1830, but the first William Jessop was in the trade long before then, and there are records of Jessops making steel in Sheffield as far back as 1774. Originally carried on in Blast Lane, the business developed remarkably at Brightside, under the direction of the brothers, Sidney and Thomas Jessop. The business was converted into a limited company in 1875, and has constantly grown, one of its latest developments being the opening of a branch establishment in America in 1902. "Iron and Coal Trades Review," July 7, 1905.

The Recent Movement of the World's Finished Iron Industry. — It is more than twenty-five years since numerous prophecies were made by "men of light and leading" in the iron trade, which, if they had come true, would have closed all the old-style mills and forges, not in this country only, but throughout the world. The sanguine supporters of the new era, ushered in by Bessemer and Siemens, believed that by this time puddled iron would be an extinct industry, and we were periodically regaled with the statement that the labor of the puddler —"the hardest work voluntarily undertaken by man," as it was deemed the correct thing to describe it — was about to end. Never was the danger of prophecy more signally demonstrated. There has not only been no extinction of the finished iron industry, but that industry still yields between five and six million tons a year of products that are as much appreciated as they ever were, and deemed quite as indispensable, or we can hardly believe that the nations and the individuals concerned would keep the business alive as they have done, and are apparently prepared to do. The great test of the utility of a product and of its consequent chance of longevity, is the extent and the tendency of its output. Judged by this standard, finished iron has, of course, lost ground both relatively and absolutely, but the loss is probably materially less than both producers and consumers were prepared to expect. However this may be, we have

collated and compiled the figures in the following table, showing that in the United States and in Europe the output of finished iron in 1904 was well over five million tons:

ROLLED IRON. — PRODUCTION IN LEADING COUNTRIES IN EACH OF THE LAST TWO YEARS

	1903	1904
United Kingdom (gross tons)	950,390	936,228
Germany (metrical tons)	819,832	765,197
France (metrical tons)	589,910	554,632
Belgium (metrical tons)	401,550	360,520
Russia and other European countries (metrical tons)	850,000	800,000
Total	3,611,682	3,416,577
Add United States (gross tons)	—	1,760,084
Grand total	—	5,176,661

The production of the United States in 1903 cannot be stated, as the figures have not been collected, but it is not likely to have differed greatly from that of 1904. The production of finished iron outside of Europe, apart from the United States, is not likely to have been very large, but it need hardly be added that every civilized country does produce a larger or smaller quantity of this material, and it is not at all improbable that the total output of all countries will not be far short of six million tons. This compares with the output of puddled iron in previous years as under:

	1880 Tons	1890 Tons
United Kingdom	2,681,150	1,923,221
United States	2,332,668	2,518,194
Germany	1,106,800	1,454,131
France	1,056,160	823,360
Belgium	493,000	506,957
Austria-Hungary	360,000	470,536
Russia	292,304	365,500
Sweden	231,143	278,700
Total	8,553,225	8,340,599

The conclusion brought home by these figures is that the finished iron trade of the world was quantitatively stronger about 1880 than it has been at any later date, and that the world's output at that period was about three and one-half mil-

lion tons more than it is at the present time, the difference being due, to the extent of about 1,700,000 tons, to the greater output of the United Kingdom, and to the extent of 573,000 tons to the larger production in 1880 of the United States, while Germany has reduced her output in the interval by 342,000 tons.

The figures submitted are necessarily more or less imperfect, and in some respects are not quite comparable, but even so they come as near as it is possible for us to get. The uniformity of statistics for which we pleaded in our issue of last week would enable us to get nearer to the actual facts. But as the case stands at present, some countries make their returns in puddled bars and others in finished steel, while a third group make their returns partly in the one and partly in the other description. A fourth group seek for "respite and nepenthe" from the distractions of records and comparisons by making no returns at all.

It is likely to be regarded by some of our readers as not a little singular that a country usually so ready to publish records of production as the United States should not for a number of years past, until last year, have attempted to publish returns of the output of wrought iron, yet such is the case. The latest records of the output of finished material under this head, previous to 1904, were collected for the year 1890, when the quantity produced was 2,518,194 tons. This appears to have been almost, if not quite, a maximum production. Previous to 1886 the maximum annual output was 2,360,649 tons in 1881; ten years further back the output was only 1,292,396 tons. The Statistical Report of the American Iron and Steel Association for 1904 goes into details of the different descriptions produced to only a very limited extent. All but about 5 per cent of the total quantity produced is grouped under the general head of merchant bars, skelp, spike rods, splice bars and other finished rolled products. The more fully specified products are rails, structural shapes, plates and sheets, nail plate and wire rods, and their aggregate only amounts to about 98,000 tons, of which over 67,000 tons take the form of plates and sheets.

The point in this inquiry that is likely to possess the most practical value for the iron trade as a whole is that of whether a continuance of the recent decay of the wrought-iron industry is to be expected, or whether that process has reached its ultimate

limits. The answer is found to a certain extent in the fact that although the process of decay has not of late years made the progress that it did at an earlier period, it has not entirely ceased. Nevertheless, the movement is still downward, and there is no sign of its probable arrest.

Our own country has for several years past fluctuated between 900,000 and 950,000 tons annually of puddled bar. Germany has in the same period varied between 765,000 and 1,000,000 tons of rolled iron. France has similarly varied between 554,000 and 650,000 tons. The future decay may be a slower process than the past has been, but it is more than likely to continue all the same. As the case stands to-day, the world's output of steel ingots is about 35,000,000 tons annually, or nearly six times the output of finished iron. The greatest output of the latter product in any one year was less than a third of the present output of steel. — "The Iron and Coal Trades Review," August 11, 1905.

Our Actual Pig-Iron Producing Capacity

Conditions during the first half of this year were unusually favorable for developing how much pig iron the United States can produce under normal conditions. There was an excellent demand for iron, yet prices were not such as to bring into play the scattered furnaces with high production costs, so that conditions in the first half of this year were a nearer approximation to those required for a full normal production, and no more, than we have had for a long time. The statistics of the American Iron and Steel Association show that production of all grades and by all fuels was 11,163,175 gross tons, exceeding by 1,455,808 tons the best previous half-yearly record, made in the first half of 1903, with 9,707,367 tons. The latest summary of total capacity is that presented in connection with the last association directory, which gives the theoretical capacity on June 1, 1904, at 28,114,000 gross tons. Some of the furnaces included in the total are furnaces which are unlikely ever to produce, but have not been definitely abandoned. The estimates of capacity in no case make allowance for relining, repairs and accidents. Accordingly, the actual capacity is always below the theoretical capacity, and the record in the first half of this year gives us a better idea than can usually

be had of how much this difference is. The production was at the rate of 22,326,350 tons per year, so that there is a difference between the theoretical maximum and the practical maximum, under normal conditions, of not more, and probably less, than 6,000,000 tons. It should be remembered that the dull period of 1904 afforded unusual opportunities for anticipating necessities of relining and other repairs, and it is a fact that the blast furnaces of the United States entered the year 1905 under better physical conditions than can usually be expected. On the other hand, there was a net increase in capacity during the half year of 748,500 tons, as shown by a recent association summary. This increased capacity contributed to some extent to the actual production in the half year. Conditions are quite favorable at the present time, and the outlook is clearly that the production in the second half of this year will somewhat exceed that in the first half, indicating a total production for the calendar year 1905 of about 23,000,000 tons. It can hardly fall a half million tons short of this, and is not likely to exceed it by a million tons. One must go back only seven years, to 1898, to find a production only about half as great, since in 1898 production was 11,773,934 tons, yet that production broke all previous records by more than 2,000,000 tons.

REVIEW OF THE IRON AND STEEL MARKET

August has hardly contributed as much improvement in the iron and steel trade as did July, but the contribution has been satisfactory nevertheless. The pig iron markets have been firm and advancing, crude steel has been very scarce, and in most finished lines there has been some improvement in demand.

While official prices of the heavier finished steel lines have not changed, there has been some heavy contracting for certain lines, and as the expiring contracts had been taken before official prices had been advanced to the recently ruling level, the result is a virtual advance, so far as the actual tonnage is concerned. Since the middle of July there has been heavy contracting for merchant steel bars, some of the contracts extending through next June. In plates a large tonnage has been contracted for 1906 delivery, for shipbuilding interests on vessels already contracted for.

There has been some improvements in all the lines which have recently been dull, including merchant pipe, wire products, sheets and tin plate.

Pig Iron. — Production of pig iron is at a slightly greater rate than on July 1 and the turn seems to have come, with prospects that production in the second half will closely approximate the unprecedented production in the first half, officially ascertained at 11,163,175 gross tons. Sales have not been as heavy in August as in July, but the market has gradually assumed a firmer tone nevertheless. The United States Steel Corporation is concluding the purchase of a large block of Bessemer pig for early delivery at $14.50, valley, equal to $15.35, Pittsburg. We now quote the market as follows: F. o. b. valley furnace: Bessemer, $14.50 to $14.75; basic, $14.50 to $14.75; No. 2 foundry, $14.25 to $14.50; gray forge, $13.75 to $13.90. Delivered Pittsburg: Bessemer, $15.35 to $15.60; basic, $15.35 to $15.60; No. 2 foundry, $15.10 to $15.35; gray forge, $14.60 to $14.75. F. o. b. Birmingham: No. 2 foundry, $11.50 to $12.00; gray forge, $10.50 to $11.00. Delivered

Philadelphia: No. 2 X foundry, $16.25 to $16.50; standard gray forge, $14.75 to $15.00. Delivered Chicago: northern No. 2 foundry, $16.25 to $16.50; malleable Bessemer, $16.50 to $16.75. Freight: Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65; to Philadelphia by water, $3.50; by all-rail, $4.00.

Steel. — Late in July the market advanced a dollar a ton on billets and 50 cents on sheet bars, to $24.00 for Bessemer billets, $25.00 for long sheet bars and $25.50 for cut sheet bars, all f. o. b. Pittsburg. Sales have not been large at these figures, but have been sufficient to thoroughly fix the market, there being no tonnage to be picked up at any lower prices. Forging billets have had good sale at high prices, ranging from $26.00 to $28.00, Pittsburg, according to tonnage and carbons. Ordinary soft open-hearth billets are about $25.00. Wire rods are quoted at $32.50, Pittsburg, and chain rods at $33.50.

Shapes. — New business in shapes cannot be placed with any of the large mills except for delivery next year. Some of the smaller mills can make deliveries on new business within two or three months. Some high prices are being paid for small lots from dealers' yards, from 2.10 to 2.50 cents for carload and larger lots. Regular mill prices remain at 1.60 cents for beams and channels, 3 to 15 inches inclusive, angles 2 x 3 to 6 x 6 inclusive, and zees, 3-inch and larger; 1.65 cents for tees 3-inch and larger, and 1.70 cents for beams and channels over 15 inches.

Plates. — The shipbuilding interests have nearly all their berths engaged for next year and have been contracting for plates against this work. Most of the tonnage has already been contracted for, plates for a few vessels but lately contracted for being now under negotiation. This business is all done at the official basis of 1.60 cents, whereas nearly all the ship plates for this year's consumption are on old contracts at 1.40 cents, so that the mills are realizing results from the advances made six months and more ago. No large orders for steel cars have been taken recently, but negotiations have been started on some large contracts. Deliveries can only be promised for next year, capacity being engaged fully for this year. The plate mills have their product practically assured for the balance of this year by actual specifications already in hand, and cannot make deliveries

on new business for many months, except in the case of a few small plate mills in the east. Official prices remain at 1.50 cents for plates 14 inches wide and under, and 1.60 cents for plates over 14 inches and not over 100 inches wide, tank quality, quarter inch and heavier.

Merchant Bars. — About the middle of July a heavy contracting movement set on for merchant steel bars, and to this writing about 500,000 tons have been sold on contracts running, in the case of agricultural implement makers through next June; in the case of most other manufacturers through December; and in the case of jobbers through the third quarter. This business was all done at the regular official price of 1.50 cents, base, half extras, f. o. b. Pittsburg. Most of the contracts expiring were at 1.30 cents. A few contracts are still running at 1.40 cents. In iron bars there has been a decided improvement, the market advancing from $1.00 to $2.00 a ton. We now quote common iron bars at 1.55 cents, Youngstown; 1.60 cents, Pittsburg; and 1.55 cents, Chicago. A few sales were made about the beginning of the month as low as 1.45 cents, Chicago, but the sharp advance in scrap prices stopped this business.

Sheets. — While there has been no sudden change in the sheet market there has been a steady gradual improvement in tonnage, which is now fairly satisfactory, while prices have not responded materially. The leading interest is now operating fully three fourths of its sheet capacity, and the independents are doing about as well. On ordinary car loads for mill shipment the market can be quoted at 2.35 cents for black and 3.40 cents for galvanized, No. 28 gauge, f. o. b. Pittsburg. On larger lots it would be possible to do about a dollar a ton less, and on very large lots, with favorable specifications and for early shipment it is possible that $2.00 less than above prices could be done. Corrugated roofing is $1.65 per square for painted and $2.85 per square for galvanized, No. 28 gauge, in carload lots. The tin-plate business has shown some improvement, but not much, it being too early for consumers to commit themselves freely against the fall canning crops. On very large lots for early delivery the leading interest is giving a special rebate of 15 cents a box, in addition to the regular 5-cent rebate from the official price of $3.55 for 100-pound cokes, f. o. b. Pittsburg. This special rebate can be withdrawn at any time.

The independents have been making about the same net prices on desirable orders. About half the leading interest's tin plate capacity is in operation, and by the end of September it is expected that nearly all its capacity will be employed. All but one of the important independent tin-plate mills have been operating full or part capacity during August.

Scrap. — Scrap prices have taken a sharp jump, more on account of the limited visible supply than because demand from consumers has improved greatly. Early in August some contracts for heavy melting stock were made at $14.00 and $14.50 delivered to mills in the Pittsburg and valley districts, but, on the short portion of some of these, dealers had to cover at a loss, paying as high as $15.35 for scrap to apply on $14.50 contracts. The market is now $15.00 to $15.50 on small lots, while it is doubtful if a large lot could be had at under $16.00, the supply being limited. Cast borings have advanced sharply and are quoted $9.50 to $10.00, delivered Pittsburg.

STATISTICS

Iron-Ore Production in 1904. — The annual statistics of iron-ore production, as compiled by John Birkinbine, of Philadelphia, have just been published by the United States Geological Survey. According to the report, the iron ore produced in 1904 was 7,374,978 tons, or 21 per cent less than in 1903, the figures for the two years being 27,644,330 as compared with 35,019,308 long tons. The continued decrease in tonnage since 1902, when a maximum production of 35,554,135 tons was reached, is in contrast to the tendency before that time when tonnage increased each year from 15,957,614 in 1895 to the high-water mark in 1902. The report suggests that, 1902 and 1903 being phenomenal years, the decrease simply indicates a return to normal conditions. The apparent consumption also fell off about 12 per cent, aggregating 30,224,910 tons for the year.

The various ores making up the total output, red hematite, brown hematite, magnetite and carbonate, were produced in much the same proportion as last year. Magnetite alone was produced in greater quantity this year than last and the carbonate ores fell off about one half. The production of red hematite, which constitutes 86 per cent of all the ore produced, fell off in the same proportion as the total production, the amount being 23,839,477 long tons against 30,328,654 tons in 1903. Of the quantity mined Minnesota contributed over one half, Michigan approximately one third, with Alabama, Wisconsin and Tennessee following in order. The decrease in the Minnesota production was most noticeable, the other states maintaining about the same output.

The total quantity of brown hematite mined in 1903 (3,080,399 long tons), decreased in 1904 to 2,146,795 long tons, a loss of 933,604 tons, or 30 per cent. Of the separate states, Alabama had the largest output of this ore, followed by Virginia, West Virginia and Tennessee. The three states producing the greater part of the magnetite were New York, New

Jersey and Pennsylvania. In New York especially the output was large owing to the activity in the Lake Champlain district, and, as a result of this large production, the total for the year rose to 1,638,846 long tons, an amount which exceeded the tonnage of 1903 (1,575,422 long tons) by 63,424 tons.

The production of carbonate ores is restricted to Ohio and Maryland and amounted to 19,212 tons in 1904 as compared with 34,833 tons in 1903, a falling off of 15,621 tons, or 45 per cent.

During the year 1904 there were produced in the United States 370,118 long tons of concentrated ore, most of which was magnetically separated. There were also made 68,189 tons of residuum, a zinc ore by-product used in the manufacture of spiegeleisen.

The states producing ore last year were identical with those of 1903 with the addition of Montana, and their respective outputs and corresponding values are given in the following table:

State	Production	Total Value at Mines	Average Value per Ton
Minnesota	12,728,835	$18,141,902	$1.43
Michigan	7,089,887	13,936,261	1.97
Alabama	3,699,881	3,744,350	1.01
New York	842,303	1,885,291	2.24
Virginia and West Virginia	550,253	951,478	1.73
Tennessee	499,949	1,126,687	2.25
New Jersey	500,982	566,813	1.13
Wisconsin	483,475	856,710	1.77
Pennsylvania	397,107	611,211	1.54
Georgia	293,802	356,950	1.22
Montana, Nevada, Texas, New Mexico, Utah and Wyoming	210,945	264,297	1.25
Colorado	150,972	429,856	2.85
North Carolina	64,347	80,440	1.25
Missouri	49,285	92,820	1.88
Kentucky	35,000	35,000	1.00
Connecticut and Massachusetts	21,990	66,839	3.04
Ohio	15,672	21,829	1.39
Maryland	9,645	18,007	1.87
Total	27,644,330	43,186,741	1.56

The Lake Superior region continued to maintain its position as the leading ore producing district in the world, and the fol-

lowing table shows in brief the output of the five ranges which comprise that region. The output of the Michipicotin Range, which amounted to but 95,887 tons, is not included.

Range	1903	1904	Decrease 1903 to 1904		Rel Part of District Output
	Long tons	Long tons	Long tons	Per ct.	Per ct.
Marquette	3,686,214	2,465,448	1,220,766	33	12.2
Menominee	4,093,320	2,871,130	1,222,190	30	14.2
Gogebic	3,422,341	2,132,898	1,289,443	37.6	10.6
Vermilion	1,918,584	1,056,430	862,154	45	5.2
Mesabi	13,452,812	11,672,405	1,780,407	13.2	57.8
	26,573,271	20,198,311	6,374,960	24	100

An inspection of the above table will show that all of the ranges have fallen off from the production of 1903, with the output of the Mesabi range, which has always been the largest producer since its inception, decreasing the least.

A very satisfactory condition for the future has been made known by the exploitation of iron-ore fields, the findings showing reserves of ore in many states that exceed the total previous output.

As a result of the slackness in the demand for and manufacture of pig iron, the quantity of iron ore imported decreased from 980,440 long tons, valued at $2,261,008, in 1903, to 487,613 long tons, valued at $1,101,384, in 1904. This importation is, in the main, from Cuba, Canada and Spain. The exports of ore, on the contrary, have steadily increased. The demand of the Canadian furnaces has steadily grown, and in recent years also the exports have been enhanced by the German demand for ores rich in iron and high in phosphorus for use in the manufacture of basic metal. The 213,865 tons of ore exported in 1904, valued at $458,823, was an increase of 133,254 tons over the 1903 movement.

Altogether the situation, while not booming at all, is very substantial. "Iron Trade Review," July 20, 1905.

Iron Production in Belgium. — The output of the Belgian blast furnaces for the five months ending May 31 is reported as follows, in metric tons:

	1904	1905	Changes
Foundry Iron	43,770	42,308	D. 1,462
Forge Iron	100,687	85,823	D. 14,864
Steel Pig	398,150	424,577	I. 26,427
Total	542,607	552,708	I. 10,101

The increase was wholly in steel pig, which includes both Bessemer and basic iron. Foundry and forge irons show decreases. The total increase was hardly expected, in view of the trouble caused to the furnaces by the coal miners' strike early in the year. " Engineering and Mining Journal," July 6, 1905.

World's Pig-Iron Production. — Returns, final in some cases, and close approximations in others, of pig-iron production in 1904 by countries which in 1903 produced about 95 per cent of the total, indicate a production in 1904 by such countries of 42,329,637 gross tons of 2,240 pounds. Assuming that the countries for which 1904 returns are not yet available to have made the same quantity in 1904 as in 1903, there is indicated a world's pig-iron production in 1904 of 44,804,150 gross tons, a decline of 1,090,563 tons from 1903, which held the record at 45,894,713 tons. In 1885 the world's pig-iron production was 19,100,000 tons, or less than half as much.

RECENT PUBLICATIONS

Fabrication de L'Acier, by H. Noble. 604 6½×10-in. pages; numerous illustrations. Vve. Ch. Dunod. Paris. 1905. Price, paper covers, $8.75; bound, $9.25. One of the most conspicuous features of this recent addition to the metallurgy of steel is the complete absence of any reference or even allusion to the work of other writers, from whom the author, nevertheless, necessarily gathered much of the information contained in his book, nor do we find any description of metallography and recent investigations into the treatment of steel. We also note the absence of any reference to the cementation and crucible processes for steel making, the work being limited to a detailed description of the Bessemer and open-hearth steel processes. The author's treatment of his subject is essentially practical, but little space being devoted to considerations of a purely theoretical character. The operations are described at length, and although they represent French practice, there is much in the author's description which should prove of interest to steel metallurgists of other countries. The practical character and exhaustiveness of the book should appeal strongly to metallurgists actually engaged in the production of steel. It is the work of an experienced steel maker who has an intimate knowledge of the operations he describes.

Modern Iron Foundry Practice, Part II, by George R. Bale. 194 5×7-in. pages; 95 illustrations. The Technical Publishing Company, Manchester (England). 1905. Price, $2.50. — This second part of Mr. Bale's well-known book deals chiefly with machine molding and molding machines, physical tests of cast iron, cleaning castings, shrinkage and distortion of castings and foundry accounting. While the author's description necessarily represents English rather than American practice, this book will be read with interest and profit by American foundrymen and, in general, by engineers interested in founding and in the physical testing of cast iron.

Concrete Steel, by W. Noble Twelvetrees. 218 5×7-in. pages; illustrated. Whittaker & Co. London and New York. 1905. Price, 6*s*. — This is a short treatise on the theory and practice of reinforced concrete construction. The size of the book and the clear and systematic treatment of the subject should appeal to the busy engineer and architect who lack the time or inclination to refer to more bulky volumes or to scattered articles.

Chemical and Metallurgical Handbook, by J. H. Cremer and G. A. Bicknell. 406 4×6-in. pages, full seal, gilt edges. Cleveland, Ohio. 1903. Price, $3.50. — This excellent handbook is of such value to metallurgists and chemists that we feel justified in noticing it in our columns two years after the publication of the last edition. The book includes useful chemical tables, mineralogical tables, tables of heat, metallurgical tables, weights and measures and mathematical tables. The information which they convey so readily is of such assistance to working chemists and metallurgists that we feel confident that very few would fail to procure a copy of the book after having examined it. Our only averse criticism refers to the table of melting points of metals on page 181, in which some of the temperatures given are not in accordance with the results of recent and accurate experiments. The melting point of aluminum, for instance, is given as 850° C., while it should be in the vicinity of 650°; the melting point of gold is given as 1147° C., while it is very close to 1064°. The melting point of nickel which is given as 1450° C. is also considerably too low.

Outlines of Industrial Chemistry, by Frank Hall Thorp, including *A Chapter on Metallurgy*, by Charles D. Demond. Second edition, revised and enlarged. 618 5½×8½-in. pages; 116 illustrations. The Macmillan Company. New York. 1905. Price, $3.50. — The first edition of Professor Thorp's book was published in 1898 and received with much favor, especially as a textbook for the teaching of industrial chemistry. In this new edition the text has been considerably revised and enlarged, this being made necessary by the important advances in the chemical industries since the appearance of the first edition. The addition of a chapter on metallurgy adds much, we think, to the value of the book, especially for those schools where metallurgy

is merely taught as a part of the course in industrial chemistry. The author divides his subject into three parts: (1) inorganic industries, (2) organic industries and (3) metallurgy. The more important industrial chemical processes are briefly, systematically and clearly described, and numerous references are given for those who desire to make a more exhaustive study of any process. This second edition of Professor Thorp's excellent work will not fail to be warmly welcomed by those interested in the teaching of this important and growing subject, and the publishers are to be congratulated for the evident care with which the book has been prepared.

James Watt, by Andrew Carnegie. 241 6×9-in. pages. Doubleday, Page & Co. New York. 1905. Price, $1.40. — The contents of this very interesting, instructive and suggestive book might be divided into two parts: first, the narrative proper of Watt's life, simply and attractively told, and, secondly, the author's comments on literary, philosophical, economical and ethical questions as occasions arise in the narrative, and which possibly form the most fascinating portion of the book. These comments are the thoughts of a thinker and of a humanist endowed with a power of expression possessed by few, and of extremely rare occurrence in men having devoted their lives to industrial pursuits and money making.

Production and Use of Petroleum in California, by Lewis E. Aubury, state mineralogist. 230 6×9-in. pages; 64 illustrations; paper covers. California State Mining Bureau. Sacramento. 1904. Price, $0.75. — In his letter of transmittal Mr. Aubury states that this bulletin (No. 32) has been prepared by Mr. Paul W. Pratzman, engineering chemist, chiefly from his own observations. The work of the bulletin has extended over two years and the greatest care has been exercised in the collection of accurate data concerning the subject treated. The aim of the bulletin is to describe the conditions under which petroleum is produced, the amount, source and character of production of same, and to outline some of the more important ways in which the output is consumed. From the reading of this bulletin the general public should obtain a clear knowledge of the conditions existing in the oil industry at the present time.

Geology of Western Ore Deposits, by Arthur Lakes, late professor of geology in the Colorado State School of Mines. New edition, rewritten and enlarged. 415 6×8-in. pages; 300 illustrations. The Kendrick Book and Stationery Company. Denver. 1005. Price, $2.50. — The author states that his object has been to illustrate the principles of mining geology rather than to dilate on any particular rich or noted mine. Colorado mines chiefly are described, and most of the illustrations are sketches from the author's pencil taken in the field. A glossary of some scientific and other terms used with mining field is appended.

Notes and Questions in Physics, by John S. Shearer, assistant professor of physics, Cornell University. 281 $5\frac{1}{2}\times 8\frac{1}{2}$-in. pages; 202 illustrations. The Macmillan Company. New York. 1904. — This book contains 1,497 problems carefully selected to illustrate physical phenomena and calculations, including the mechanics of solids, liquids and gases, heat, magnetism, electricity, sound and light. Some useful physical and mathematical tables are also appended. The author claims, undoubtedly on good ground, that students continually complain of their inability to solve simple problems in physics, which is a clear indication that the fundamental principles are not fully grasped, and that concrete, practical examples are needed to bring out the sense of the terms used. In order to suggest methods, a few typical cases have been fully solved in the text. It is somewhat regrettable that the answers to the problems have not been included, because this omission decreases the value of the book for the private student. The book is well printed and illustrated and attractively bound.

Western Mill and Smelter Methods of Analysis, by Philip H. Argall. 124 $5\frac{1}{2}\times 7\frac{1}{2}$-in. pages; illustrated. Industrial Printing and Publishing Company. Denver, Colo. 1905. Price, $1.50. — This book consists of a description of the methods of analysis used in lead and copper smelters and in cyanide mills in the Western states. The chapter on the cyanide process, including a detailed description of the daily work of the chemist, should prove of value to those interested in that process. It is claimed by the publishers to be the most practical synopsis of the subject ever written.

Moody's Manual of Railroads and Corporation Securities, 1905. 2,642 6½×9-in. pages. Moody Publishing Company. New York. 1905. Price, cloth, $10.; full leather, $12. — This new edition of "Moody's Manual of Railroads and Corporation Securities" is so comprehensive and complete that the claim made by the publishers that the book is superior in every department to that of any publication in the country is a statement that cannot be repudiated. The book is four inches thick and weighs over twelve pounds. It contains over three million words and covers the entire field of corporation investments. There are ten sections to the volume, and each section has been prepared by its own special experts, who have made it their entire work to make the book complete and up-to-date in every possible sense of the word.

It is probably the most accurate and complete steam railroad reference book in existence; it is the only electric traction book that undertakes to cover the entire field in this comprehensive way; it is the only reference book containing a section on gas and electric light companies of the country; it is the only book containing a section on water-supply companies; it is the only reference book containing a section on telephone and telegraph companies; it is the only book containing a section on industrial and miscellaneous corporations which is in any sense uniform and complete; and it is the only investment manual containing reports on mines and oil corporations. Furthermore, it is the only book in the United States which contains anything like complete statements of banking and financial institutions, showing the essential facts of interest to investors in bank or trust company stocks. It is also the only book containing complete and up-to-date lists of the members of the twenty-five stock exchanges of the cities of the United States.

The publishers state that since the publishing of the first edition, which appeared in 1900, the growth in pages has been over 140 per cent; the growth in the size of this volume over the first edition is 100 per cent; the increase in quantity of contents as compared with the first edition is over 800 per cent; and the increase of the current edition in circulation over that of 1900 is over 400 per cent.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

793,110. Gas-Purifer. — Edward A. Uehling, Passaic, N. J.

793,137. Electric-Magnetic Ore Separator. — Erich Langguth, Euskirchen, Germany.

793,268. Metal-Annealing Furnace. — Darwin Bates and George W. Peard, Huyton, England.

793,305. Gas-Producer. — Ernst Korting, F. Paul, Jr., Peekskill, N. Y., assignor, by direct and mesne assignments, to Henry Amling, Jr., New York, N. Y.

793,350. Tuyere for Forges. — John Christian, Hydraulic, Colo., and Louis S. Judd, Oak Park, Ill.

793,377. Casting Plant. — Joseph G. Johnston, Detroit, Mich., assignor to American Car and Foundry Company, St. Louis, Mo.

793,380. Blowing-Engine. — Albert T. Keller, Wilkinsburg, Pa.

793,425. Apparatus for Forming Pipe-Molds. — Jacob K. Dimmick, Philadelphia, Pa.

793,467. Tuyere-Iron. — Soren P. Petersen and Wilson Toups, Patterson, La.

793,501. Annealing Furnace. — Carl Bechstein, Cannstatt, Germany.

793,544. Apparatus for Purifying Blast-Furnace Gases. — Walter Schwarz, Dortmund, Germany.

793,554. Gas-Producer. — William Viggers and Rowland Z. Ball, Durango, Mexico.

793,745. Means for Removing Dust from Gases. — John Shields, Willesden Green, England.

793,806. Furnace-Charging Apparatus. — George Schuhmann, Reading, Pa., assignor to Reading Iron Company, Incorporated, Reading, Pa.

793,852. Furnace-Charging Box. — Cameron C. Smith, Pittsburg, Pa.

793,877. Ingot-Delivery Car. — Thomas James, Braddock, Pa.

794,000. Process of Purifying Gas. — Adalbert W. Fischer, Philadelphia, Pa., assignor to Schutte & Koerting Company, Philadelphia, Pa.

794,153. Utilization of Flue-Dust. — Charles S. Price, Westmont, Pa.

794,201. Centrifugal Gas-Purifying Apparatus. — Edward Theisen, Baden-Baden, Germany.

794,386. Furnace-Charging Apparatus. — Ralph Baggaley, Pittsburg, Pa.

794,391. Furnace-Charging Device. — John J. Boax, McKeesport, Pa., assignor to National Tube Company, Pittsburg, Pa., a corporation of New Jersey.

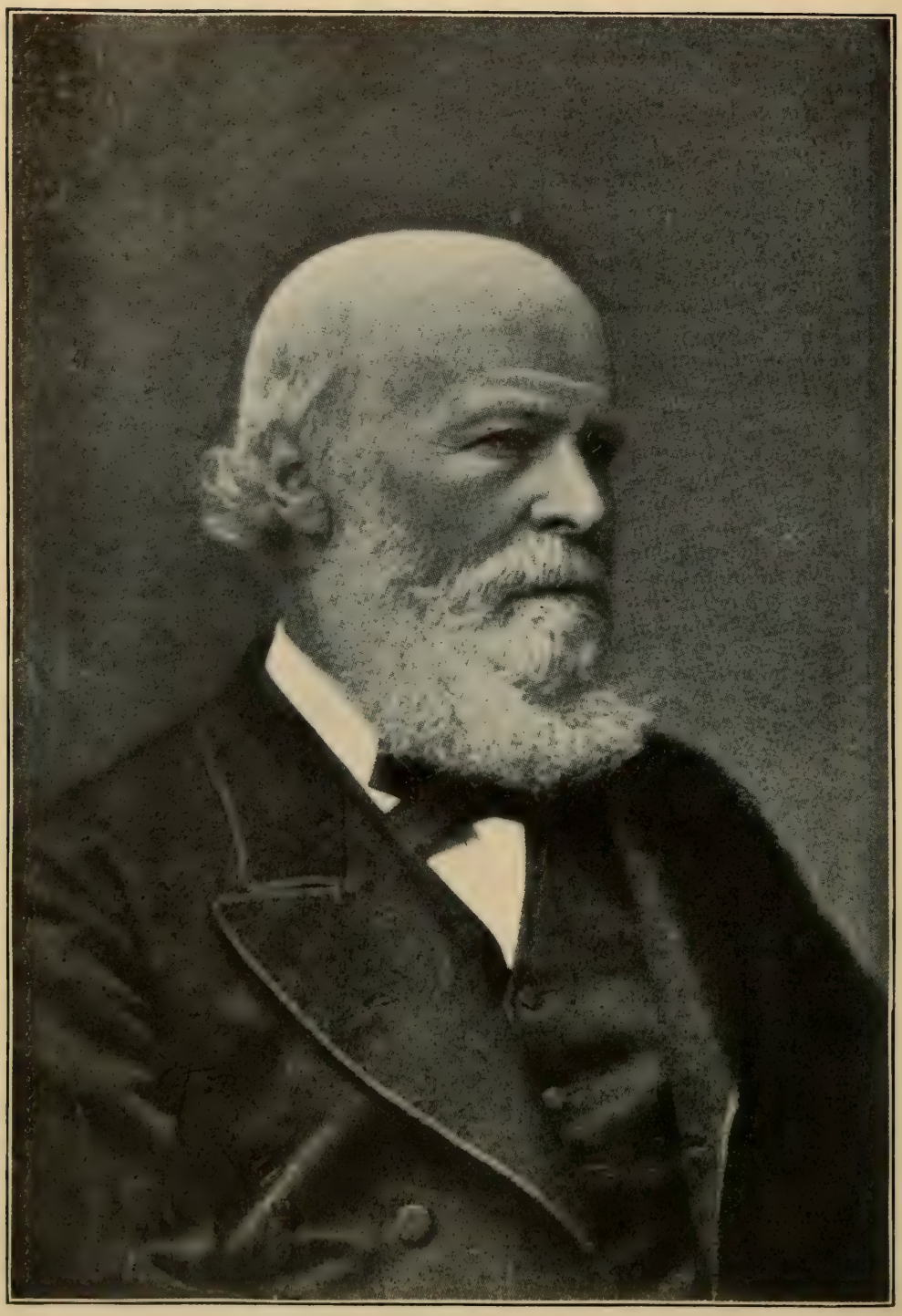
GREAT BRITAIN

11,437 of 1904. Briquetting Iron Ores. — E. Goldschmid, Frankfort, Germany. Heating friable iron ores in a water-gas furnace in order to obtain coherent masses suitable for smelting.

12,367. Gas-Producer. — Alfred B. Duff, Pittsburg, Pa.

13,594 of 1904. Dust Collecting. — B. H. Thwaite, T. J. Denny and R. E. Commans, London. Collecting the dust given off at the working faces of mines by means of powerful suction pipes.

411 of 1905. Smelting Iron Ore. — J. Gayley, New York. In smelting iron ores with a dried-air blast, using much less coke than is theoretically required, the explanation of this economy not being quite clear.



SIR LOWTHIAN BELL

SEE PAGE 354

The Iron and Steel Magazine

"..... Je veux au mond publier
d'une plume de fer sur un papier d'acier."

Vol. X October, 1905 No. 4

ELECTRIC STEEL *

By F. W. HARBORD

THE great interest which the manufacture of steel in the electric furnace has aroused, both amongst manufacturers and engineers in this country, and the fact that there is already one electric furnace in Sheffield and that it is reported that another Sheffield company has acquired the exclusive patent rights of the well-known Héroult process for the British Isles, make it important that we should consider the possibilities of electric smelting relative to steel manufacture in England.

While, on the one hand, the extravagant claims urged on behalf of electric smelting — that it will revolutionize the manufacture of structural steels as at present made by the Bessemer and open-hearth process — may be dismissed as nonsense, the attempts, on the other hand, to prove that it cannot compete with the crucible process in the manufacture of tool steels, or the open-hearth furnace for many of the higher class steels intermediate between these and common structural steel, may equally be disregarded. The truth lies between these two extremes, and the manufacturer who realizes this and takes advantage of the great possibilities which the electric furnace offers to meet very many of the special steel requirements of to-day, and who does so with judgment and knowledge, will, without doubt, be in a most exceptional position, not only to meet foreign competition, but to more than hold his own against his British competitors. Since the Canadian Commission visited Europe last

* "The Times Engineering Supplement," August 2, 1905.

year, rather more than a year has elapsed.* During this time very considerable quantities of electric steel have been made both in Sweden and in France, and have been used with most satisfactory results for all classes of tools and cutlery, and for various other purposes for which the highest class crucible steel was formerly employed, confirming in every way the conclusions of the Commission that "steel equal in all respects to the best Sheffield crucible steel can be made." Considerable quantities of this steel have been supplied to Sheffield firms, who have thus been able to convince themselves of its exceptionally high quality, and it now only remains for our Sheffield people to make the steel for themselves, rather than import it. The manufacture of crucible steel for tool purposes, important as it is to the country, owing to the world-wide reputation for quality which it has acquired, is, however, only one comparatively small branch of our great steel industry; and perhaps the most important question is, to what extent electric smelting can be employed for the manufacture of the numerous classes of steels between this and ordinary Bessemer, or open-hearth steel.

We import annually very large quantities of Swedish Bessemer steel for tube blanks, for the solid drawn tube trade, and for other purposes too numerous to mention; again, large quantities of Swedish pig irons are imported for use in our open-hearth furnaces for the manufacture of special qualities of high-class steel for large forgings, axles, tires, special wire and other purposes, and in many cases steel of the required composition can only be made by using, either entirely or in part, these very high-priced pig irons. Another very important branch of the steel trade is the production of dynamo steel of exceptional purity and low hysteresis, and in this direction the electric furnace promises great things, as steel of the greatest purity, low in carbon and manganese, can readily be produced. If we add to these the manufacture of all kinds of ordnance, armor plate, projectiles, rifle, bayonet and other high-class steel, we see that, without attempting to compete with Bessemer or ordinary open-hearth structural steel, there is an immense field open to the electric furnace. Numerous experiments have shown that electric steel is not only extremely pure, but it is also exceptionally

* A review of this report of the Commission appeared in "The Times Engineering Supplement," March 8.

homogeneous, and this is a most important point in the manufacture of large steel castings. When it is remembered that, for special purposes, castings, sometimes of fifty to sixty tons, have to be made by mixing the contents of a number of crucibles not containing more than 1 cwt. each, the advantages of being able to make steel equal in all respects as to quality, in quantities of fifteen tons and possibly more, will readily be apparent.

If steel to satisfy the exacting requirements of the highest class of tool steel can be produced, there can be no question as to the production of steel of a quality suitable for what we may term medium-class steels, and it then becomes simply a question of cost, and whether the electric furnace can compete in this respect with Swedish Bessemer steel, or steel made from Swedish pig iron, or steel of specially selected English brands.

In the electric furnace of the resistance type, which may be said to be represented by the Héroult and Keller furnaces, the highest class steel can be made from ordinary English scrap, such as rail ends, but against the saving effected in this direction has to be set the cost of the electric energy required. The electric furnace, even under the best conditions, is not a cheap melter, but as a refining furnace towards the end of the operation, when a very high temperature is required, it is far more efficient; it therefore seems probable that the future development of the electric furnace will be in combination with some form of continuous open-hearth process, in which molten pig iron is first converted into what we may term "molten scrap steel" in a gas-fired furnace, and then transferred in the molten state to the electric furnace for final purification. By this means the additional cost over ordinary open-hearth steel would be comparatively small, the melting and preliminary refining having been done in the gas-fired furnace, and the electric furnace being employed only to do the final refining at such high temperatures as those at which it alone is able to work most efficiently and economically.

The design of the Héroult furnace, so far as the general construction is concerned, is particularly well adapted to work in combination with an open-hearth tilting furnace, and if, instead of charging cold scrap, or even molten pig iron, converted metal were charged on some such lines as suggested, a steel superior to best Swedish steel, or steel made from Swedish

pig iron, should be obtained at a less cost. Given a large output, so that labor costs are reduced to a *minimum*, the price at which such a steel could be produced would, no doubt, induce many manufacturers to employ it for purposes for which at present they are content to use inferior steel, and thus it would soon create a demand for high-class material, apart from that already existing. It is not suggested that a simple refining of ordinary steel in this way would be sufficient for the production of the highest class of tool steels. For the production of these, it would no doubt be necessary to carry on the operation in the electric furnace in a way similar to that employed at La Praz, at a considerably greater cost as to expenditure of electric energy, time and labor; but in these cases the process is not competing with the open-hearth method, but with the crucible process, in which, although the output may be comparatively small, there is a much greater margin as regards cost of production, and the question of a pound or so a ton is of no great consequence.

There are two other types of furnaces, known as (1) the induction furnace and (2) the arc furnace, which are now competing with the resistance furnace for the favor of the English steelmaker. The former is represented by the Kjellin furnace, which has been at work for several years in Sweden, and the latter by the Stassano furnace, which has been at work for a considerable time in Italy. The Kjellin furnace is quite distinct both in principle and construction from the Héroult furnace, whilst the difference between the principle of the latter and arc furnaces generally is not so clearly marked, and they merge one into the other. But this classification will be sufficient for practical purposes. In general arrangement, and also as regards electrical and other details, the Stassano furnace is totally distinct from the Héroult, and it was primarily designed for the direct smelting of iron ore rather than for steel making, although it has been producing steel most satisfactorily for some time. From a practical engineering and metallurgical standpoint, however, there can be no doubt that the Héroult furnace is far better designed to meet the general requirements of the steel manufacturer than either the Stassano or the Kjellin furnace.

It is understood that a furnace of the latter type is already at work in Sheffield, and there can be no question as to the

quality of the steel produced, provided high-class material, such as Walloon scrap, is used for its production. In Sweden, where a furnace is attached to works producing this high-class scrap, probably this furnace is as good, and may, under such conditions, be even better than the Héroult; but the objection to it under English conditions is its lack of adaptability, both as regards the materials which can be used, and in any variation in design to suit the conditions of our practice. In reality it is a large melting crucible, and to get the highest class of steel it is necessary, just as in the crucible process, to charge the purest materials, as the amount of purification which takes place during the operation is practically very small. On the other hand, the Héroult process can deal with ordinary English scrap or pig iron, and by the repeated addition of suitable fluxes to form new slags, the impurities can be removed, so that a final product is obtained quite equal, if not superior, to much that is made from Swedish materials in a crucible.

That steel made in an electric furnace should possess superior properties to steel of similar composition produced either in a Swedish Bessemer converter, or in an open-hearth steel furnace, may seem at first to be claiming a great deal, but such appears to be undoubtedly the fact, and this is due probably to its production in what may be regarded as a practically neutral atmosphere, under conditions in which the occlusion of gases and over-oxidation is reduced to a *minimum*.

It is frequently urged that the cost of electric energy in this country makes the production of steel in anything like quantities a commercial impossibility; but with electric energy at £10 per kilowatt year, at which price it can be produced under favorable conditions from coal, and by using the gas furnace for the melting, and the electric furnace only for the final operation, the difference in cost, as regards electric energy, will probably be more than met by the lower price of our raw material, and our proximity to markets for the sale of the finished product. When the irregularity in supply, due to the change of seasons, and the generally inaccessible position and remoteness from sources of supply, and from markets for the sale of the finished product are taken into consideration, the much-talked-of cheap production of electric energy from water power will often be found to be more apparent than real.

THE GALBRAITH ELECTRIC IRON AND STEEL FURNACE *

A SUCCESSFUL treatment of iron sand would be an important step in advance. Iron sands abound in many localities. The term is used both for grainy magnetite — a combination of iron oxides corresponding more or less to the formula Fe_3O_4 — and for the ore known to the mineralogist as menachanite (from Menachan, in Cornwall) and by other names, an oxide of iron and titanium, with 30 and more per cent of the latter. Both the ores are either too compact for direct reduction, or so finely divided that they trickle through the furnace, and most attempts to transform these ores into briquettes have failed. Gröndal and Mathesius are said, however, to have succeeded, each in his own way, in making suitable iron-sand briquettes. In any case, however, the new process which the Galbraith Iron and Steel Company, Limited, of Auckland, New Zealand, demonstrated at the Brush Electrical Engineering Company's works, at Loughborough, Leicestershire, on Wednesday last, would deserve close attention. The main features of this process are the following: The iron sand mixed with carbon is passed through a furnace so as to fall as a shower in a zigzag path through a number of carbon grids heated by the current, until, melted and reduced, it arrives in the receptacle below. The whole furnace is sealed, and open only at the feed-hole above, so that no air can enter, otherwise the grids or incandescents, as the inventors, Messrs. J. K. Shirreff Galbraith and William Steuart, call them, would be burned. The charge is further met on its downward path by reducing gases. Low potential currents are utilized. Neither flux nor fuel, in the ordinary sense, is needed, and the iron or steel, which collects in the receiver in the shape of beans, is said to be free of the titanium contained in the ore. An admixture of 1 per cent would not be objected to by metallurgists in most cases; often a higher percentage of titanium could be tolerated, and for certain steels some titanium is considered a desirable constituent.

The raw material comes from Taranaki Bay, in New Zealand, where it covers miles of the beach. This iron sand has,

* "Engineering," July 21, 1905. Abridged.

so far, practically no value, and if the inventors do not accomplish more than to transform the very fine black powder into beans suitable for Bessemerizing or other treatment, they will have achieved an object on which vast sums have, so far, been spent in vain. The fine sand is passed through magnetic separators. It is very pure, and the impure and the purified ore shown differed hardly in appearance. We give analyses of the ore and of the steel resulting from another less pure sample of ore taken from a breakwater:

	Ore Per cent		Steel Per cent
Peroxide of iron	67.04	Carbon by combustion	2.891
Protoxide of iron	30.17	Silicon	0.201
Manganese peroxide	0.22	Sulphur	0.189
Aluminum oxide	0.16	Phosphorus	0.453
Silica	0.50	Arsenic	nil
Calcium and magnesium	traces	Manganese	0.137
Titanium	1.6	Copper	0.24
Undetermined	0.31	Iron	96.095
		Titanium	nil
	100.00		100.206

The titanium percentage may rise to 4 per cent. The titanium is supposed to pass into the slag, but there are hardly any constituents to form a slag with. The ore was supposed to be free from phosphorus; the material just now worked on does, however, contain some phosphorus.

The ore is mixed with coal dust and heated, for a few minutes only, in a crucible. This roasting, or preheating, would, in a commercial plant, be performed in a rotatory kiln or in some other less primitive way. The furnace itself is built up of a framing of graphite, holding horizontal grids, likewise of graphite; the grid-bars form obtuse-angled roofs. Four of these grids are confined in one tier, and three tiers are arranged above one another, so that the charge shower falls, in descending, over twelve bars in succession and finally into the receiver — an iron box — below. Between the bars, or incandescents, interceptors are to be placed; these interceptors are of the same shape as the incandescents, but they are not so thick, and their bars are closer together. In this demonstration furnace only one intercepter was used, at the very top of the furnace; through this intercepter grid the charge trickled down in three streams.

The incandescents and intercepters are made by the Morgan Crucible Company of Battersea.

Each incandescent, it will be understood, forms a rectangular horizontal frame, against the front and the back of which iron bars are pressed. In the furnace which formed the subject of Wednesday's experiment, a good contact between the front and the iron was secured with the aid of weighted levers; this pressure forced the backs of the grids against the bars at the back. The current leads, copper bars, or ribbons, were screwed to the iron; there were twelve circuits, one for each grid. Mr. Gardner, who assisted in the experiment, put in about a pound of charge per minute, and a current of 100 kilowatts at 18 volts was stated to be used. The waste of power and heat in this skeleton furnace was, of course, great. But furnaces of this type are to be constructed with walls of bauxite, and it should be possible to cool the electrodes with the aid of water-jackets. No figures as to the economy of the process can be given under the circumstances. Through peep-holes, closed by mica, the metal could be seen to trickle down into the receiver in big drops, which united to ordinary size beans, and further fused together, as the receiver was not cooled. Specimens of steel obtained in the furnace were exhibited.

We should only like to make one remark as to the power consumption by such melting or smelting operations. Ruthenburg has claimed to melt his ore at an expenditure of heat energy below the theoretical figure. That is not inconceivable, for it would suffice to melt a portion of the ore which would cake together with other particles. In actual practice the charge would pass hot direct from the rotatory kiln into the furnace, and the final product would be remelted in a crucible or converter. The carbon percentage, about two in demonstration samples, could more or less be regulated, if not in the furnace, certainly in the converter. The furnace used for the demonstration was certainly very experimental; but it did something so far not accomplished, and it may perform its work economically. Though it is too early yet to express any opinion on this point, we heartily wish the inventors success. Mr. Albert Robins is secretary of the Galbraith Iron and Steel Company, of Auckland, whose London offices are at the Cannon Street Hotel, E. C.

THE MELTING POINTS OF SLAGS AND OTHER MEMBERS OF THE SERIES SiO_2–Al_2O_3–CaO *

By CLIFFORD RICHARDSON, Director New York Testing Laboratory, Long Island City, N. Y.

THE presentation of a paper before a recent meeting of the Iron and Steel Institute, May, 1905, by O. Boudouard, entitled, "Experiments on the Fusibility of Blast-Furnace Slags,"† has again attracted attention to a subject the literature of which has been quite abundant in recent years. To review this in its entirety would be burdensome, but it will be worth while to call attention to the fact that many of the melting points and the conclusions drawn therefrom, which are contained in the paper of Boudouard, and in the "Silikatschmelzlösungen" of J. H. L. Von Vogt,‡ are very seriously in error, as shown by the work of Day and Allen on "The Thermal Properties of Feldspars," § and by the investigations of the writer on "The Constitution of Portland Cement from a Physico-Chemical Standpoint." ‖

If we examine the data given in the second volume of Von Vogt, published in 1904, we shall find a résumé of the melting points of a large number of native minerals as determined by prominent investigators: Doelter with the pyrometer, Joly and Cusack with the meldometer, and Brun with Seger cones. To select a few examples, it appears that wollastonite was found to have a melting point of about 1245°, augite in the neighborhood of 1160°, the amphiboles from 945° to 1135°, the olivine group between 1065° and 1400°, while anorthite was found by Doelter to have a fusing point of from 1124° to 1190°, and by Brun of 1500°. With the exception of the latter determination the results are all suspiciously low. That this suspicion is not

* Received August 16, 1905.

† Abstract. "The Iron and Steel Magazine," Boston, Mass., Vol. X, No. 1, July, 1905, p. 53.

‡ "Die Silikatschmelzlösungen," J. H. L. Von Vogt, Christiania, 1904.

§ "The Isomorphism and Thermal Properties of the Feldspars," Arthur L. Day and E. T. Allen. "The American Journal of Science," Vol. XIX, February, 1905, and publication of Carnegie Institute, Washington, D. C., 1905.

‖ "The Constitution of Portland Cement from a Physico-Chemical Standpoint," Clifford Richardson, Long Island City, N. Y., 1904.

unfounded can be seen from the results of the very careful examinations of Day and Allen on the melting point of anorthite, which was found by them to be 1532°. If we refer to the tri-axial diagram given in Boudouard's paper, we find that the locus of anorthite would indicate a melting point of 1500°.

In the discussion of the total heat of fusion of the various minerals, Vogt assumes its melting point to be 1200°. His determination, and that of Doelter, are over 300° out of the way. Brun and Boudouard are nearer the correct figure, and as close as could be expected with the means which they employed for the determination. He similarly assumes equally low figures, in the neighborhood of 1200°, for the fusing point of diopside, microcline, akermanite and other silicates. From the writer's observation these figures are as much out of the way as the anorthite determination. Boudouard is as much in error in his statements as to the melting points of the more basic compounds as is Vogt in regard to anorthite and the other natural silicates.

On examining Boudouard's tri-axial diagram it will be found that, while his figures for the melting points of the aluminates of lime and silicates of alumina of various degrees of basicity are fairly correct, considering the method which he employed for determining them, those which he gives for the silicates of lime are so far out of the way that it would seem that he could not have had these materials actually in hand. It is a well-known fact to those who have studied the basic silicates of lime from the point of view of their relation to the constitution of Portland cement that di- and tri-calcic silicate can only be fused at a temperature above the melting point of platinum.* It has also been plainly shown by the writer that silica, alumina and lime, when combined in the proportions necessary for the production of a Portland cement, while fusing at a lower temperature than the simple silicates, melt at a higher temperature than platinum. According to Boudouard's tri-axial diagram the compounds included in the area correspond to the composition of pure Portland cement and melt between

* "The Constitution of Portland Cement," Clifford Richardson. "Cement," Progress Publishing Company, New York, 1904, Vol. V, No. 3, p. 124.

1450° and 1470°, while di-calcic silicate is shown with a melting point of 1460°, and the tri-calcic silicate with a melting point of 1500°.

It appears, therefore, that Vogt is entirely out of the way in his conclusions in regard to the melting point of the feldspars, as shown by Day and Allen, while Boudouard's data in regard to the more basic compounds are equally incorrect. While the writer cannot say that the melting points for the slags which Boudouard gives are equally erroneous, it is plain that a cloud is cast upon all his statements from the fact that he is so far in error in regard to the compounds, the fusing points of which are well known.

To those who are interested in the accurate determination of the fusing points of slags and silicates, the work of Day and Allen is recommended as showing the great care and refinement of manipulation which is necessary for such determinations, it being the only work which bears upon its face evidence of the highest degree of accuracy.

Boudouard's methods are open to very serious criticism. He determines the melting point by a comparison of the behavior of the material to be examined, when made into a proof cone of the exact dimensions of the Seger cone, with Seger cones of known melting point. He states that the Seger cones are made from Fontainebleau sand, white marble and calcined alumina made from ammonia-alum, ground to such a degree of fineness as to pass through a No. 100 sieve (with 1,370 holes to the square centimeter), but not through No. 150 (with 3,080 holes to the square centimeter). It is a well-known fact, which has been shown by various investigators of the constitution of Portland cement, that materials as coarse as this do not readily attain equilibrium except on exposure for a very long period of time to temperatures above that of the heat of formation. The di- and tri-basic silicates of lime can only be formed in a state of equilibrium when the silica and lime of which they are made have been reduced to such an impalpable state that they will remain suspended in water for a very considerable length of time, and the same may be said of the solid solution of aluminates in silicates which form Portland cement. In the case of coarse materials the resulting compounds are always in metastable equilibrium, or are found, under the microscope, to have an entirely

different structure from those produced from the impalpably fine powder.*

In view of these facts, the Seger cones prepared by Boudouard can hardly have furnished a proper indication of the points of fusion of the more basic compounds which he has represented in his tri-axial diagram. It is plain, too, that exact determinations can only be made on the lines followed by Day and Allen, and that all melting points of members of the series SiO_2–Al_2O_3–CaO which have been published are far from the truth, in most instances, and open to very serious criticism

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DESCRIPTIVE METALLURGY OF IRON AND STEEL.† II

By SAMUEL GROVES

(*Continued from page 199*)

Ores in Nature

IT is a remarkable fact that in nature things which are of vital importance to the existence and evolution of man are universal — either in adaptability or diffusion. For example, wheat, "the staff of life," is the only cereal which can be grown in every clime. Iron, "the king of metals," is found in every part of the globe.

Universal Diffusion. — As W. Mattieu Williams has said, we cannot dig up a spadeful of earth without finding oxide of iron. No geological formation is free from it. It is found in the ocean, in mineral springs, in the red blood, in the atmosphere, in the very heavens above. So rarely is it absent from the soil that a bed of sand free from it is as valuable as a gold mine. Glass-workers have no little difficulty in getting such supplies. Clay free from iron oxide is of great value to the potter. The

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* "The Constitution of Hydraulic Cements," S. B. Newberry and W. B. Newberry. "The Jour. Soc. of Chem. Ind.," 1897, Vol. XVI, p. 887.

"The Constitution of Portland Cement," Clifford Richardson. "Cement," Progress Publishing Company, New York, 1904, Vol. V, No. 3, p. 124.

† "The Canadian Engineer," September, 1905.

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prevailing reddish brown color of the earth is due to iron. Snow is looked upon as an emblem of purity, and yet within the Arctic Circle one cannot evaporate a handful of snow without leaving behind a sediment containing darkish particles which jump to a magnet.

It does not need high powers of inductive reasoning to perceive in this phenomenon of the universal diffusion of iron a wonderful example of design in nature. Without metals man would have remained a savage. Louis Figuier has luminously enforced this view in his " Primitive Man ":

" There can be no doubt that the free use of or privation from metals is a question of life and death for any nation. When we take into account the important part that is played by metals in all modern communities, we cannot fail to be convinced that without metals civilization would have been impossible. That astonishing scientific and industrial movement which this nineteenth century [1876] presents to us in its most remarkable form, the material comfort which existing generations are enjoying, all our mechanical appliances, manufactures of such diverse kinds, books and arts, — not one of all these benefits for man, in the absence of metals, could ever have come into existence. Without the help of metal, man would have been condemned to live in great discomfort; but, aided by this irresistible lever, his powers have been increased a hundredfold, and man's empire has been gradually extended over the whole of nature."

Origin of Iron Ores in Nature. — The popular scientific theory is that in the beginning the matter which constitutes the round globe upon which we live existed as a fiery mist floating in space. In some way — we call it *gravitation* — the particles of incandescent gaseous star dust (by mutual attraction) ran together and condensed into a globular mass, which gradually cooled, forming a solid crust, enveloped by dense, seething metallic vapors, holding in suspension carbonic acid, oxide of iron, siliceous sand, aluminous clay, magnesia, phosphates, sulphate of lime, etc. At first, the metallic rain which poured down boiled off again on approaching the heated surface. After a time, however, this metallic rain ceased to rise again, and remained part of the solidifying earth. Then came the birth of vegetable life, colossal palms and immense ferns. It is well

known that plants, under the action of light on their green cells, decompose carbonic acid and liberate oxygen. Now the earth's atmosphere at this stage — known as the carboniferous period of geology, was densely laden with carbonic acid; but in time this was abstracted and absorbed by the great forests and swamps with their rank vegetable growths, thus clearing the atmosphere and making the earth's surface habitable for animal life. As the broad forests and widespread swamps became submerged, either by the action of glaciers or subsidence of the earth, the buried organic matter, consisting largely of carbon, taken from the atmosphere, was petrified into *coal;* while the immense areas exposed to the oxygenated atmosphere gradually died, decomposed and decayed, evolving in the process carbonic acid, which attracted to itself the surrounding oxide of iron, silica, alumina, magnesia, sulphates, phosphates, etc., and gradually solidified into beds of iron ore, even one hundred feet thick, as in Lake Superior, U. S. A. (Fig. 3), and in India. The various depths and angles at which these layers or strata are found being mainly due to volcanic eruption and upheaval of the earth's crust.

Having glanced at the nebular hypothesis of La Place, as the best scientific explanation of the origin of iron ore in nature, let us now follow this up by one or two illustrative proofs furnished by modern research.

Aërolites. — Native iron in a metallic state is very rare. It is one of the pet schemes of the metallurgical chemist to form pure iron in the laboratory; but even then it has to be kept hermetically sealed, otherwise it is attacked by the oxygen in the atmosphere and quickly transformed into oxide of iron. If exposed long enough it will crumble into dust. Nearly all iron found in a metallic condition is of terrestrial origin, and is never pure, for in the aërolitic form it is invariably alloyed with other metals, such as nickel, cobalt, manganese, etc. The use of aërolites in iron working is as old as history. Amerigo Vespucci, after whom the North American continent is named, tells us that in the fifteenth century the Indians at the mouth of the La Plata River made their arrow heads of iron extracted from aërolites. Certain Siberian tribes are known to make their knives from this source, and a like practice exists among the Laplanders. Indeed, some writers have set up the fanciful theory that the

working of iron began with the use of these metallic stones dropped from the skies. It is true these stones of terrestrial origin are found in all parts of the earth, varying in size from mere dust grains to masses weighing tons.

Fig. 1 is a photographic picture of "Ahnighito," the largest meteoric mass of native iron ore known to be in existence in the world. It was discovered by Commodore Robert E. Peary, United States Navy, at Cape York, Greenland, in 1894, and is now in the American Museum of Natural History, New York. It is 11 feet long, 7½ feet thick, and weighs 37 tons. The



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FIG. 1. Largest Aërolite Known to be in Existence

mass of metallic iron is alloyed with 8 per cent nickel and a little cobalt.

In Fig. 2 is shown a diagrammatic section of the Egremont mine on the northwest coast of England, illustrating the remarkable manner in which strata of red hematite ore are sometimes found imbedded in thick layers of limestone. As the waters, heavily laden with vegetable matter in process of decomposition and hence highly carbonized, flowed through the limestone, it dissolved out large quantities of the rock, thus forming great cavities and caverns. Now the Old Red Sandstone is rich

in iron. In fact its reddish color is due to oxide of iron, just as the red color of the blood is due to iron. When, therefore, either by grinding glacier or raging torrent, denudation of the sandstone rocks took place, the oxide in the finely divided particles of sand was dissolved by the vegetable acids into carbonate of protoxide of iron. As this solution of iron floated along in the drift it was acted upon by the oxygenated atmosphere, iridescent films would appear on the surface of the flood, indicating that the protoxide had been transformed into peroxide of iron. These insoluble films of iron oxide, being of higher specific gravity than the rest of the drifting material, and

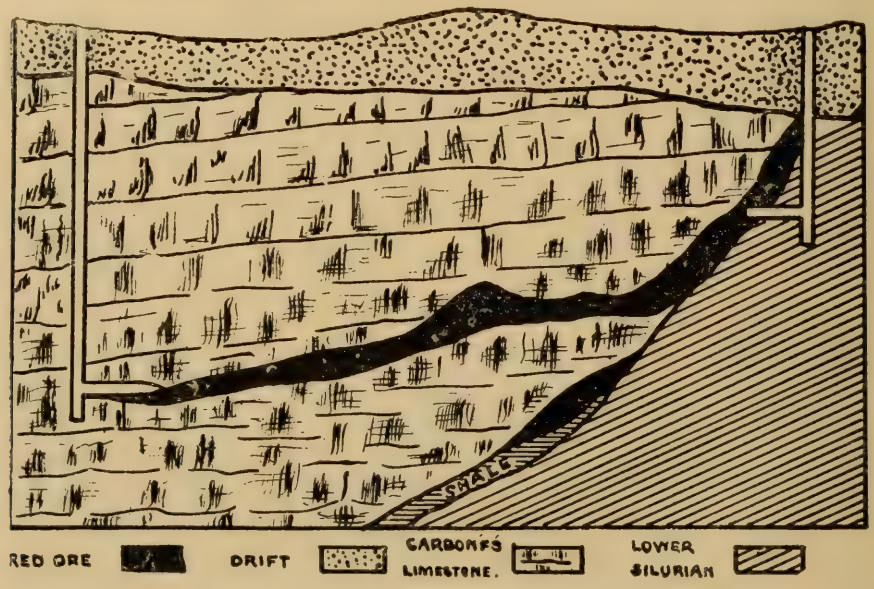


FIG 2. Egremont Mine, England

becoming heavy masses by the addition of new particles, sank to the bottom, filling up the cavities and deep fissures, and gradually solidified into solid beds of red hæmatite iron ore, as illustrated in Fig. 2.

To a like origin may be traced the formation of the famous bed of hematite ore in the Chapin Mine, near Iron Mountain, Mich., U. S. A. (Fig. 3).

This is the greatest deep mine deposit of ore being worked in the world to-day, and was opened in 1880. It consists of four lenticular deposits, 2,500 feet long, 130 feet wide, depth unknown. The ore contains 63 per cent of metallic iron, 0.07 per cent phosphorus.

Phosphorus. — Mention of the phosphoric contents of the Chapin Mine ore opens the way for an explanation of the reason why the extensive beds of carbonate iron ores which abound in the Eston Hills of Yorkshire, England, and in the broad seams running from New Jersey, through Pennsylvania, down to Alabama in the United States, contain as high as 2.75 per cent of phosphorus; while the 1,000,000,000 tons of hematite iron ores buried in the Mesabi range and Lake Superior district, U. S. A., are practically free from this mortal enemy of the steelmaker.

Popularly stated, there are three periods in geological time: (1) Silurian: age of invertebrates; (2) Devonian: age of vertebrate fishes; (3) Carboniferous: age of coal plants, ver-

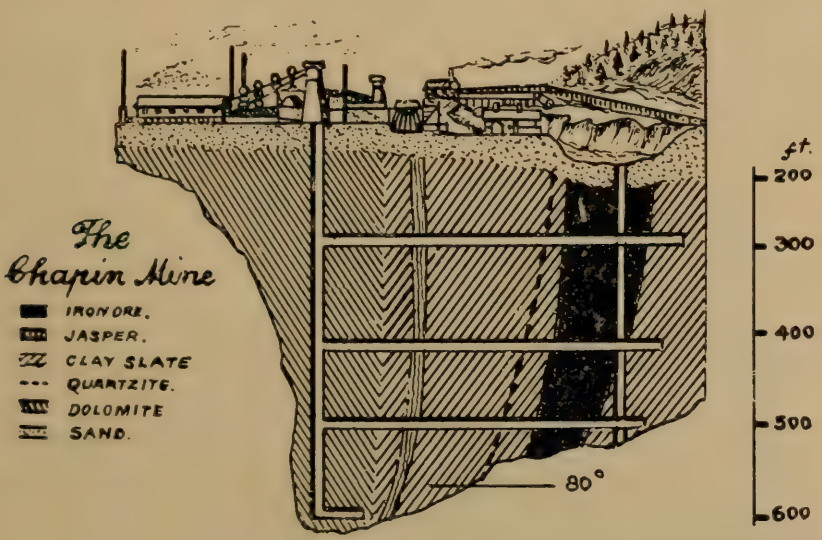


FIG 3. The Chapin Mine, U. S. A.

tebrates, amphibians and reptiles. It is a well established induction of science that the existence of phosphorus in iron ores is due to the remains of decayed fishes and animals. It is also a fact that the solid framework of the invertebrate animals which existed in the Silurian period consisted of carbonate of lime, whereas the bony structure of the vertebrates, which existed in the later Devonian and Carboniferous periods, was made up of phosphate of lime. Now the high phosphorous ores of the Cleveland district of England, and Pennsylvania, U. S. A., are all found in beds of the Carboniferous age, in close proximity to the great coal measures, when fishes, amphibians and reptiles abounded; and it is from the decayed bones of these extinct

vertebrates that the excessive phosphorus is derived. On the other hand, the Lake Superior hematite ores are all found in the levels of the Silurian age when vertebrates did not exist; only shells of mollusks, corals, crinoids, trilobites and other invertebrates, as already stated. The solid framework of these creatures consisted not of phosphate, but carbonate of lime, hence the comparative freedom of these iron ores from phosphorus.

Modern Ore Making. — If proof is needed of the foregoing theory of the origin of iron ores, the reader can have actual demonstration before his eyes in Canada to-day. About midway between Montreal and Quebec in the valley of the St. Maurice, where the river flows from the north into the St. Lawrence, is Lac à la Tortue (Turtle Lake), a body of water four miles long, by one and one-quarter miles in average width, situated in the middle of a swampy morass. The environing land consists largely of sand, doubtless carried down from the archæan rocks in the vicinage, by the erosive and grinding action of glaciers.

Standing on the western shore, the traveler gazes in imagination upon a primeval scene. Innumerable streams and rivulets may be seen winding and percolating their way down to the lake, through the sand rich in oxide of iron. These running waters are laden with the decaying vegetable matter which grows rank in the marshy lands, carrying with it quantities of the sand, saturated with iron oxide. The organic acids evolved by the decomposition of the vegetable stuff dissolve the oxide of iron, which is carried to the lake. But as it floats down, this solution of protoxide of iron is acted upon by the atmospheric air, oxidation takes place and a remarkable phenomenon is perceived. Patches of iridescent film appear on the surface of the lake, looking like petroleum with its rainbow colors, indicating that the soluble protoxide has been transformed into insoluble sesquioxide of iron. The reason this peroxide film appears in patches is due to concentrationary action; the particles aggregate themselves into batches, which sink to the bottom of the lake in the form of cakes ranging up to ten inches diameter or more; hence the term " cake ore."

This brown hematite lake ore contains 70 per cent of metallic iron, and seems inexhaustible; for with the decay of



FIG 4. Mountain Iron Mine, 1904

each year's vegetation, new supplies of iron from the sands are deposited in the lake. These rich lake ores have been used in the St. Maurice furnace at Radnor since 1752. In 1775 one of the lessees of the Radnor furnace aided the American colonists by casting shot and shell — made from the lake ores — to be used against Quebec.

Lac à la Tortue and a neighboring lake are the only known instances of the kind on the American continent.

Deep mine formations like those of the Chapin Mine, and lake bottom deposits similar to that of Lac à la Tortue, are, however, mineralogical curiosities when compared with the magnificent surface deposits of the Mesabi range in Lake Superior country. We are almost bewildered with the marvellous prodigality of nature when we look upon awe-inspiring scenes like that pictured in Fig. 4. Gazing upon this stupendous work of man, we are impressed with the same sense of grandeur and majesty as we are upon first beholding Niagara Falls; one caused by the mighty hydraulic forces of nature, the other by the engineering skill and inventive genius of man.

And this is only one of the series of enormous holes made in scooping out with giant shovels 79,000,000 tons of ore in the past twelve years. There is 75 miles run of these beds of soft hematite ores, containing 50 per cent of metallic iron and practically free from phosphorus.

Having described the *modus operandi* in which ores are formed in nature, we now pass on to a consideration of the properties of the ores of commerce.

(*To be continued*)

METALLOGRAPHY APPLIED TO FOUNDRY PRACTICE *

PART III

By ALBERT SAUVEUR

Microscopical Examination of Prepared Samples

AFTER a sample of cast iron has been polished and etched as described in the first two installments of this article, it is ready to be examined under the microscope. The apparatus needed to carry on this examination will be briefly described.

The Microscope. — While any good microscope of the ordinary type may be used with some degree of success for the examination of samples of metal, a special stand, as illustrated in Fig. 1, is almost a necessity for effective work. It differs from the ordinary type by the motion of the stage, which can be raised or lowered by rack and pinion mechanism. The advantage of this feature will be appreciated later on upon considering the illumination of the sample.

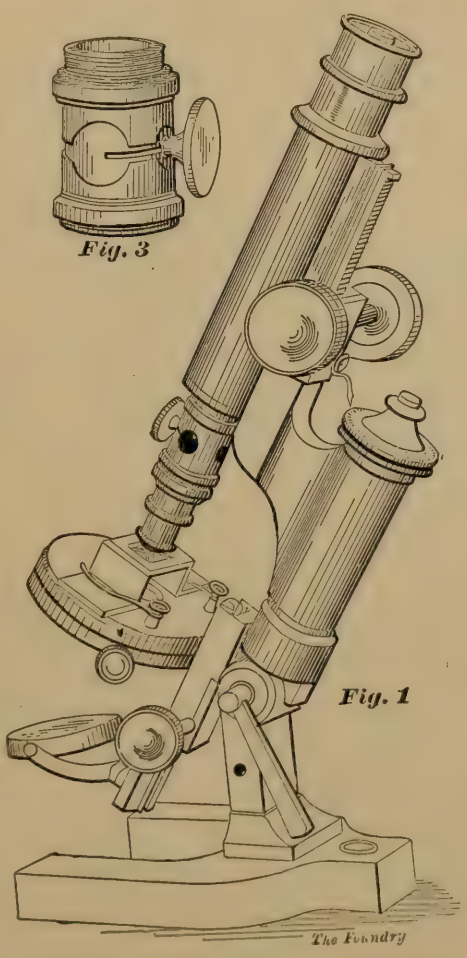


Fig. 3

Fig. 1

The microscope shown in Fig. 1 is manufactured by the Bausch & Lomb Optical Company, of Rochester, N. Y., and is the instrument universally used in the United States for the examination of metals. The microscopical outfit should include one low-power objective (one half or two thirds of an inch focal length), one high power objective (one sixth or one eighth of an inch focal length) and two eyepieces, respectively of one-inch and two-inch focal length. These will yield the different magnifications and resolutions which are needed for a successful examination of the structure of cast

* "The Foundry," September, 1905.

iron, it being very seldom that higher or lower magnifications are found necessary.

When examining a specimen of metal under the microscope it is absolutely necessary to bring the polished surface in a plane exactly perpendicular to the axis of the instrument, and unless some special device be used for holding the sample in this position, this means that the polished surface and the opposite side must be exactly parallel, so that when the sample rests upon the stage of the microscope, the upper surface will be in the proper position. The difficulty and labor implied by the cutting of two exactly parallel surfaces will be readily appreciated. To obviate this necessity, the special specimen holder illustrated in Fig. 2 will be found most effective. A rubber band holds the

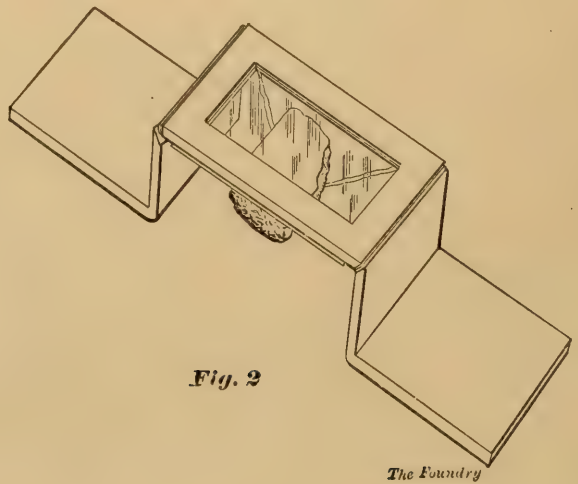


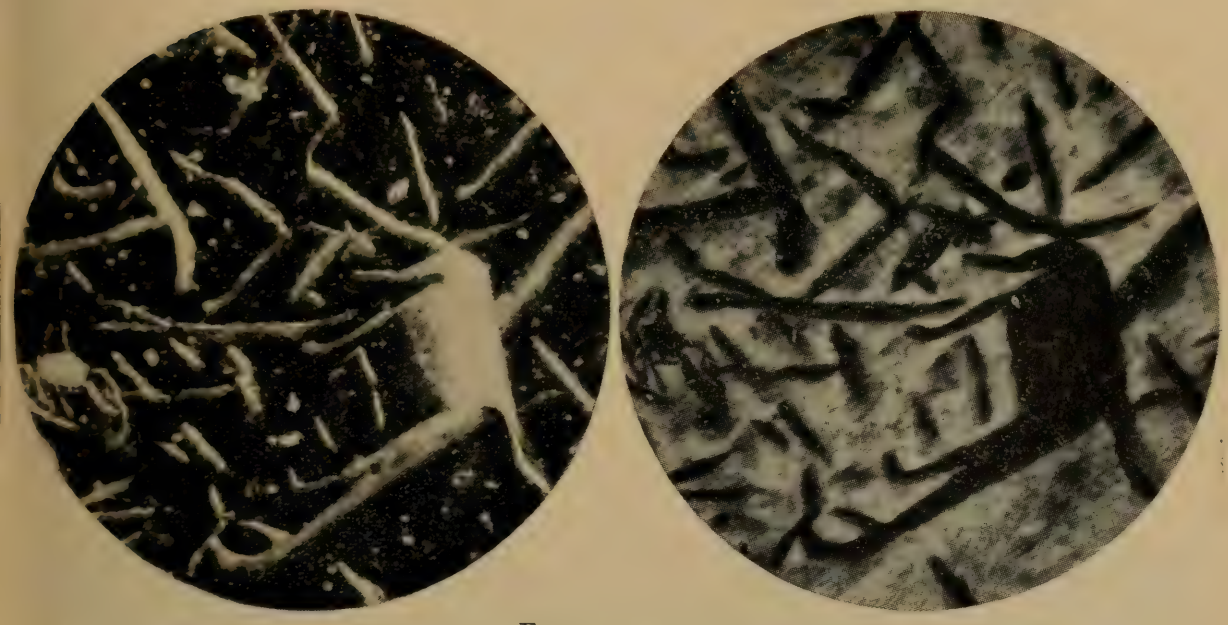
Fig. 2

The Foundry

specimen firmly in the holder, however irregular in shape, and a cover glass may be inserted between it and the object so as to fulfill the requirements called for by the correction of the objectives. The holder is then placed on the stage where it can be clipped like any ordinary microscopic slide. (See Fig. 1.)

Illumination of the Sample. — Metallic samples are absolutely opaque objects and, unlike the ordinary transparent slides of other microscopists, cannot be illuminated by transmitted light; that is, by light sent from below the stage through the object. Reflected light, that is, light thrown from above upon the specimen, must of necessity be used. This light may be reflected obliquely upon the specimen, directly from the source of light or with the assistance of a mirror or of a condenser, or it may be

reflected vertically upon the sample by the lenses themselves of the objective by means of a device known as a vertical illuminator and which affords by far the best illumination of opaque objects. This illuminator, which is shown in Fig. 3, consists of a small glass disk, supported by a milled head, which controls its position, and is inserted between the objective and the nose of the microscope, as shown in Fig. 1. The light from the source of light enters the illuminator through a lateral aperture and is reflected downwards by the little glass disk through the lenses of the objective, which condenses the light upon the



FIGS. 4 AND 5

sample. The light emitted by the lighted portion of the specimen re-enters the objective, passes in part through the glass disk, then through the eye-piece, reaching the eye of the observer and producing an enlarged image in the usual way.

Obliquely vs. Vertically Reflected Light. — It will readily be seen that obliquely reflected light can be used only with relatively low power objectives, because high-power lenses must be brought too close to the object to allow any beam of light to reach the latter from without. Obliquely reflected light, moreover, yields, so to speak, a negative image of the true appearance of the sample, because the bright constituents reflecting the

light outside the microscope will appear dark, while the dark constituents, by absorbing and diffusing the light, reflect some of it into the tube of the microscope and appear bright. Vertical illumination, on the contrary, yields a true image of the appearance of the object.

In Figs 4 and 5 are shown the structure of exactly the same spot of a sample of gray cast iron, but illuminated respectively

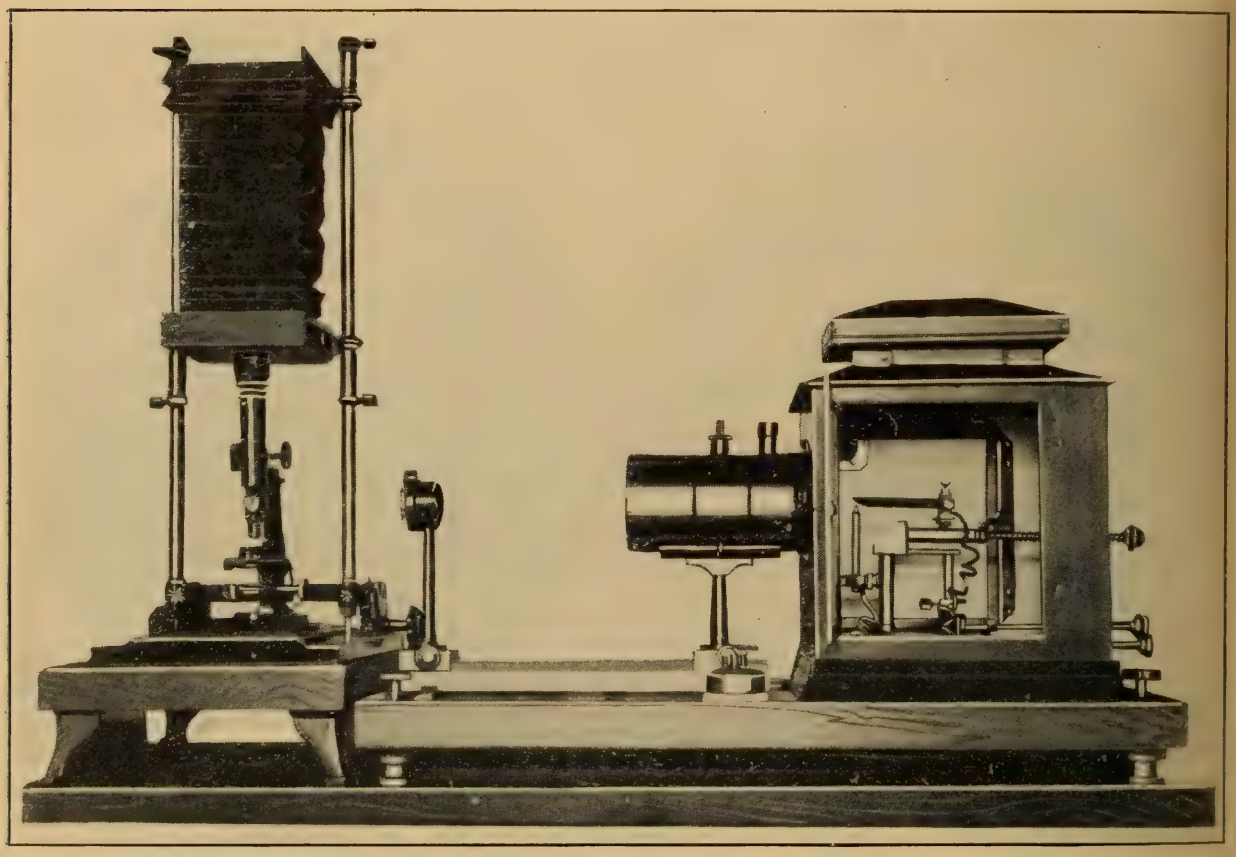


FIG. 6. Special Arc Lamp for Opaque Objects

with obliquely and vertically reflected light. It illustrates strikingly the opposite effects produced by these two kinds of illuminations. In Fig. 4 the plates of graphite appear bright, while they are black in Fig. 5, and therefore with their true color. The iron matrix, on the contrary, is dark in Fig. 4 and light in Fig. 5. In view of these considerations, it will be obvious that vertically reflected light is generally the best means of illuminating metallic samples.

Sources of Light. — Many artificial lights may be used to obtain a satisfactory illumination of metallic samples, but it will suffice to mention here the two sources which are most generally used, namely, the electric arc lamp and the Welsbach lamp. Fig. 6 illustrates a special arc lamp and accessories for the illumination of opaque objects. The outfit consists of an electric

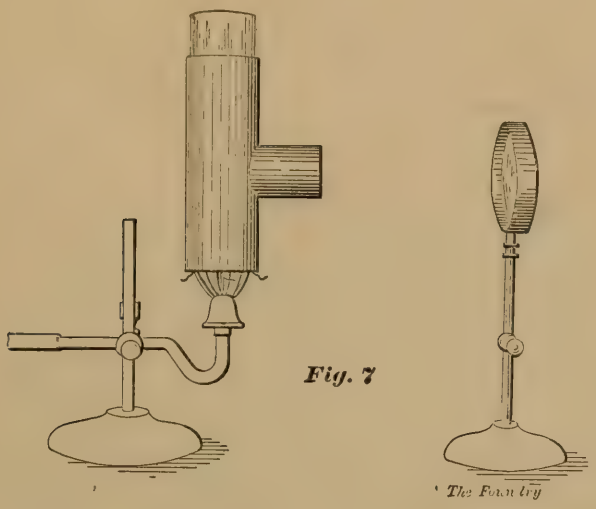


Fig. 7

90-degree arc lamp and rheostat, a triple condenser system, a cooling cell, an iris diaphragm and automatic shutter, an optical bench and base board. The illustration also shows the microscope connected with a camera for taking photo-micrographs.

In Fig. 7 is seen a simple Welsbach lamp and condenser, an arrangement which yields a very satisfactory illumination for examination by low-power objectives.

SPECIAL STEELS *

By L. GUILLET

TERNARY alloys and steels are those in which the alloy consists of iron, carbon and an intentionally added metal, the other constituents being kept within the usual limits. In the following description of certain of these steels, the author's investigations have been concerned with two grades, one containing only about 0.2 per cent of carbon, the other approximating to the eutectic and containing about 0.8 per cent of carbon.

The mechanical tests were of three classes, — tensile strain, shock by the Fremont method and hardness by the Brinell method. The tensile tests were performed on standard test bars, but with the tungsten steel the bars were 200 mm. long between the punch marks, the others measuring half that length; the diameter in all cases was 13.6 mm.

Nickel Steel. — This steel has received so much attention in the "Journal of the Iron and Steel Institute," and in the papers of Riley, Osmond, Dumas, Hadfield, Hopkinson, Guillaume and others, that we do not propose to review at length the author's investigations on this alloy.

Manganese Steels and Chrome Steels. — The remark made above applies equally to these alloys.

Tungsten Steel. — There is no difficulty in producing tungsten steel in the crucible furnace with a high temperature. The usual proportions of tungsten are 0.5 to 13 per cent (except for spring steel, which will be referred to later). Either ferrotungsten or the metal itself may be employed; the former, containing 8 to 9 per cent of carbon and about 80 per cent of tungsten, is prepared in the electric furnace, while the metal is obtained either by this means or the aluminothermic process.

The diagrams furnished by the mechanical tests performed on the crude steel demonstrate that the breaking strain of the pearlitic steels increases in proportion with the tungsten content. The limit of elasticity does not increase with the same rapidity, while the reduction of area and elongation suffer little diminu-

* From a paper presented before the Mining and Metallurgical Congress in connection with the exhibition at Liége, Belgium, June, 1905.

tion. Under the Fremont test their fragility is not greater than that of carbon steel, and as a rule their hardness is superior to that of ordinary steel with the same carbon content. The carbide steels have a high breaking strain, directly proportional with the percentage of carbon, but not increasing in proportion to the amount of tungsten. The limits of elasticity are relatively low and the reduction of area and elongation very small. These steels border on the class of brittle steels and present the remarkable feature that their resistance to shock is nearly constant, whatever the percentages of carbon and tungsten present. Finally, the hardness increases with the proportion of carbon.

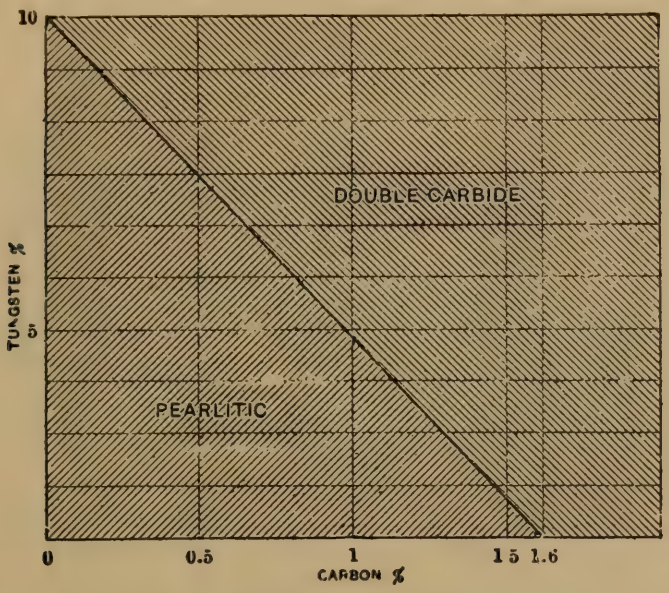


FIG. 1. Diagram of Tungsten Steels

If a diagram be constructed of the tungsten steels, Fig. 1, the straight line drawn from the point indicating 1.6 per cent of carbon to that relating to 10 per cent of tungsten will divide the steels into the groups of pearlitic and carbide steels respectively.

At present the tungsten steels are chiefly used in the manufacture of tools, the low-grade steels requiring to be tempered in water, while the high-grade varieties are self-tempering, though they require an admixture of chromium or manganese for that purpose. Some steel makers have put tungsten spring steel on the market, the average composition of the product

being: Carbon, 0.47; manganese, 0.22; silica, 0.20; and tungsten, 0.6 per cent.

The untempered steels give the following values: breaking strain, 113,500 to 120,900 pounds per square inch; elongation, 14 per cent; elasticity, 85,000 pounds; these being modified by tempering and suitable annealing to 199,000 pounds, 7 per cent, and 142,000 pounds, respectively. These steels do not seem to be much superior to the silicon steels generally used, being very high in price and more brittle than silicon steel when tempered and annealed.

Molybdenum Steels. — These are prepared in a manner similar to that employed for tungsten steel. Under mechanical tests the pearlite steels (0.5–2 per cent of Mo) have a far higher breaking strain than ordinary steels, the elongation and reduc-

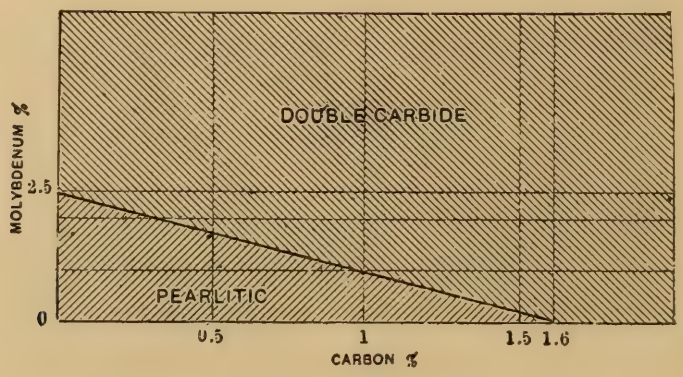


FIG. 2. Diagram of Molybdenum Steels

tion of area being also very good. They are, moreover, harder, though not more brittle, than carbon steels. The double carbide steels have very high breaking strains and limits of elasticity, with only slight elongation and reduction of area, and they are brittle and extremely hard. The line of demarcation between the groups of pearlite and double carbide steels runs from 1.6 per cent of carbon to 2.5 per cent of molybdenum (Fig. 2).

Molybdenum steel was put upon the market as a special tool steel of some mysterious quality, but has since been abandoned, the steel being not much better than tungsten steel, while the price is higher, though the proportion of added metal is smaller. Nevertheless, some makers continue to use molybdenum and tungsten together.

Vanadium Steels. — The tests above mentioned were applied to vanadium steels that had been slightly annealed by heating to 900° C. and slowly recooling, this treatment being rendered necessary by the fact that these steels are more profoundly modified by working than others. The grades high in vanadium are very irregular, owing to the low density of the double carbide leading to its uneven distribution throughout the mass. Tests applied to different parts of the same bar gave the following results at the two ends:

Steel with 0.382 per cent of carbon and 5.37 per cent of vanadium: breaking strain, 48,000 to 78,000 pounds; elasticity, 22,000 to 49,000 pounds; elongation, 23 to 17 per cent.

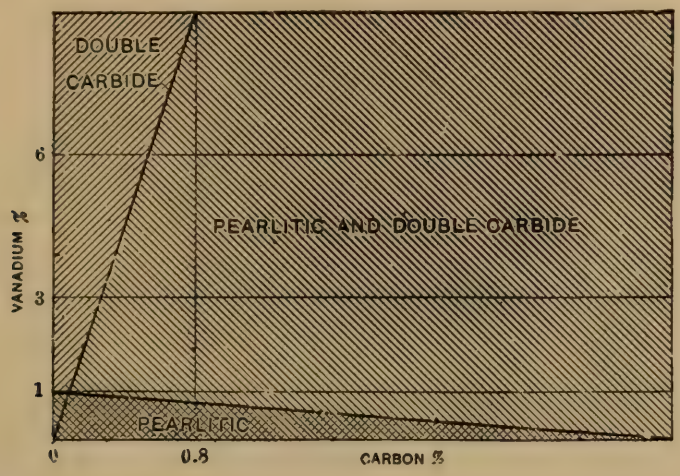


FIG. 3. Diagram of Vanadium Steels

Steel with 0.130 per cent of carbon and 7.37 per cent of vanadium: breaking strain, 40,000 to 75,000 pounds; elasticity, 28,400 pounds; elongation, 21 to 17 per cent.

Steel with 0.120 per cent of carbon and 10.27 per cent of vanadium: breaking strain, 43,000 to 77,800 pounds; elasticity, 29,800 to 67,000 pounds; elongation, 22 to 21.5 per cent.

Steel with 0.737 per cent of carbon and 7.85 per cent of vanadium: breaking strain, 43,000 to 77,800 pounds; elasticity, 19,000 to 57,000 pounds; elongation, 16 to 22 per cent.

Steels with 0.858 per cent of carbon and 10.25 per cent of vanadium: breaking strain, 59,000 to 100,200 pounds; elasticity, 24,100 pounds to 44,800 pounds; elongation, 10-10 per cent. Here the breaking strain and elasticity increased pro-

gressively from one end of the bars to the other, the increase corresponding to higher percentages of carbide (determined by the micrographical examination of the fractured surfaces).

The diagram furnished by these steels shows that in addition to the pearlite and double carbide groups, they form a third group containing both these components; also that the larger the percentage of carbon, the more vanadium is required to keep the whole of the carbon in the condition of carbide (Fig. 3).

The net result of the tests is to exclude from industrial application all grades containing over 0.7 per cent of vanadium, such of them as contain carbide being practically useless. The characteristic property of vanadium is to impart hardness to the steel and increase the breaking strain and limit of elasticity. In fact, in this respect, the metal plays a part similar to carbon and at least as powerfully as the latter. Another interesting property of vanadium is that in raising the breaking strain and limit of elasticity, it does not diminish the elongation, nor does it produce the slightest fragility; these remarks applying, of course, to the permissible limit of the metal as given above.

It follows that nothing stands in the way of an extensive utilization of vanadium steels (which are not difficult to manufacture), provided they can be produced cheaply. At present, the cost of ferro-vanadium is failing, for whereas a short time ago it was worth about 44*s*. per pound of vanadium present, American makers have latterly offered it as low as 14*s*. 6*d*. It is evident, therefore, that since the most valuable vanadium steels are those containing 0.2 to 0.5 per cent, the extra cost of adding these quantities to ordinary steel is really negligible (6*s*. to 16*s*. per ton). Nevertheless, it must not be forgotten that vanadium steels are very sensitive to thermal and mechanical treatment, and that they cannot be used until they have been carefully annealed by heating to 900° C. and gradually recooled. The author is convinced that steels containing less than 0.7 per cent of vanadium have a great future before them, comparable in every way to that of pearlite nickel steels.

Titanium Steels. — Much has been heard of the advantages of titanium steel in a general way, without any definite particulars respecting their valuable properties; and for this reason a systematic study of the series appeared to be of in-

terest. The specimens experimented upon were prepared with ferro-titanium produced in the electric furnace, but could not be made of higher titanium content than 10 to 15 per cent, the temperature of the ordinary crucible furnace being insufficient to fuse the higher alloys. The results were, however, disappointing, so far as any improvement in the breaking strength, hardness and resistance to shock are concerned, these steels being devoid of any practical interest. This circumstance does not preclude the possibility of using titanium as a purifying agent.

Cobalt Steels. — There is no difficulty in the manufacture of these steels, metallic cobalt being used. Its influence on the properties of the iron differs from that of nickel, at least up to a cobalt content of 30 per cent and a carbon content of 0.8 per cent, the products being all of the pearlitic group.

The mechanical tests, too, show that apart from a slight increase in the breaking strength, cobalt has very little influence in any proportion between $4\frac{1}{2}$ per cent and 30 per cent; consequently, the cobalt steels are of no industrial interest.

Tin Steels. — Tin acts much in the same way as silicon and titanium, but does not play the same important part as the former in steel; it will not precipitate carbon in the form of graphite. Up to nearly 5 per cent it is dissolved by the iron, but at that limit a definite stannide of iron seems to be formed. The carbide, up to 10 per cent, at least, always remains in the form of pearlite.

Steel containing 1.5 per cent of tin is very difficult to forge, and above 2 per cent renders it unworkable. The steel becomes extremely brittle, breaking into small fragments under the shock of conveyance from place to place; and if the bars are dropped from a height of about three feet on to a flagstone, they are reduced almost to powder. Though a sufficient percentage (about 5 per cent) of tin makes the steel very hard, there is no practical use for any member of the series.

Classification of Ternary Steels

The special steels may be classified in the following manner:

(1) The added metal lowers the conversion points of the iron, and gives three groups, — pearlite, martensite and γ-iron steels. This class comprises nickel and manganese.

(2) The conversion points are lowered and, in addition, a double carbide is formed, the three groups then being, pearlite, martensite and double-carbide steels. Chromium belongs to this class.

(3) The added metal (tungsten, molybdenum and vanadium) is capable of forming a carbide, so that we have two groups: pearlite and double-carbide steels.

(4) The added substance precipitates carbon in the condition of graphite, and gives two groups of steel, one containing combined carbon, the other graphitic. This is the case with silicon.

(5) The metal dissolves in the iron, and gives in all cases pearlite steels. Such metals are cobalt, titanium and tin.

The micrographic character of special steels furnishes in some instances valuable indications as to their mechanical properties. In the case of pearlite steels, however, these indications are merely partial, the mechanical properties depending on the element dissolved in the iron or in the pearlite (for instance, a pearlite tin steel is of no use). Hence, mechanical tests must be made to determine the quality of the steel. With a martensitic steel, on the contrary, it may be at once concluded that it has high breaking strength and limit of elasticity, with low elongation and slight reduction of area, is brittle, hard and difficult to work. A polyhedral steel will have a rather low limit of elasticity but high elongation, great power of resisting concussion, and may be more or less hard according to the substances dissolved in the pig iron. If the structure of the steel indicates a carbide, chrome steel is revealed by round grains, tungsten, or molybdenum steel by fine filaments, and vanadium steel by large triangular granules. The presence of graphite in steel argues extreme fragility and practically no elongation or reduction of area.

Uses of Ternary Steels. — A certain number of pearlitic steels can and should be used in place of carbon steels. This is principally the case with nickel steels, and to some extent also with manganese steels.

Of the martensitic steels, a few only are suitable for constructional uses, owing to their general fragility and difficulty in working them. Some, however, may be used in making tools or for particular purposes.

The polyhedral steels, if cheaper, would have a great future before them. At present they can only be used in special cases, and, moreover, they have a very low limit of elasticity.

Among the double-carbide group, the tungsten and molybdenum steels are likely to be in good demand, by reason of their great hardness on tempering. Besides, they are already in general use as tool steel. Finally, the graphite steels are useless for practical purposes.

The author also deals with some quarternary steels, *i.e.*, those in which the steel is alloyed with carbon and two other intentionally added elements. The steels dealt with are the nickel-chrome, chrome-tungsten and manganese-silicon steels, which are in every-day use. Experiments have also been made with nickel-manganese, nickel-silicon and nickel-vanadium steels, which have not yet come into general use. The consideration of these must, however, be deferred.

HOT CRACKS IN STEEL CASTINGS*

By ARTHUR SIMONSON

AN attempt will be made in the following article to outline the principal causes of one of the greatest difficulties that a steel founder has to contend with, and to suggest some means by which it may be overcome, at least partially. Cracks in steel castings are of two kinds, which differ in their appearance and cause very materially. Hot cracks take place at the time of solidification of the metal or very soon after; cold cracks are formed while the metal is below red heat. The former take the appearance of a tear, are very ragged and there is a sinking of the metal at the edges; they are generally quite wide and have a film of blue or black oxide on their fractured surfaces. Cold cracks, while they may be open occasionally, are generally very fine, clean cut as with a knife, and unless the castings are carefully inspected may sometimes escape observation. Ringing the castings with a hammer will often reveal the presence of cold cracks which are almost invisible. It is with the former, or hot cracks, that the present article is intended to deal.

* "The Foundry," August, 1905.

The two principal causes of hot cracks are obstructions to the free contraction of the metal, and unsuitable composition of the metal itself. First, then, look into the causes which may prevent the unrestricted contraction of the metal. They are chiefly the rigidity of the mold and the varying thicknesses of section of the casting. The mold has to be made sufficiently strong to stand the weight of the steel and the fluid pressure of the head of metal while it is being poured. Molds for steel castings are generally made in dried sand, which consists of silica sand mixed with a certain proportion of clay to bind it together. And though it is very weak in its green or damp condition, it becomes quite hard and firm after baking. The molds are faced with a wash made of silica flour and molasses water, which gives a very hard, refractory skin. It is, therefore, important that while the mold should be strong enough to stand all the pressure it is to receive, it should not be any stronger than is necessary for the above purpose. Means may be provided for making the mold stronger in some parts than others, for instance near the gate, where the cutting action is greatest. At these places the mold may be made of a stronger grade of sand, or, if its shape allows, hard cores or firebricks cut to shape may be fitted in, to take the wear of the stream of metal. All square corners, both inside and outside, should be amply filleted, and wherever a rib or a projecting arm of the pattern protrudes, the sand in its immediate vicinity should be loosened up by ramming in cinders, sharp sand or sawdust; or the mold can be cut away to within two or three inches of the pattern, after it has been dried, and the space filled in with burnt sand.

Another point to be attended to with the idea of reducing the danger of hot cracks is the drying of the molds. To produce the best results a mold should be rather over-dried than underdried; that is to say, it should be almost but not quite burned. A mold that is only just dry is in the most rigid possible condition; it can be baked a good deal more and yet preserve sufficient strength to stand the wear and tear of pouring, and it will then offer much less resistance to the shrinkage of the metal. The ideal mold, as has been said before, consists of a hard refractory skin and a collapsible backing, which will give way as soon as the cooling skin of the casting has become sufficiently rigid to support itself, and begins to shrink. It is to the production of

these conditions as nearly as may be possible in practice that foundrymen have to bend their efforts.

Defective construction of cores is another fruitful source of cracked castings. Coremaking is a branch of the steel foundry trade that does not receive the attention it merits. It is equally as important as the mold itself, calls for as much skill and contributes equally to the success or failure. And yet we often find the coremaking relegated to a very secondary place. Core sand mixtures should be as carefully studied as molding sand mixtures, and a great saving may be effected, not only in the matter of cracking, but in the cost of cleaning and the soundness of the castings by careful attention to this point. The same description applies to a core as to a mold,— it should have a hard, smooth face, which will resist the cutting and fusing action of the metal, but it should crumble and fall out in the form of powder when burnt. Careful handling will permit the use of cores which seemingly are exceedingly delicate. As the writer has previously stated, cores can be made of almost anything, provided the wash is all right. When the core is rammed up it should have a good coat of a wash made of silica flour, ceylon graphite and molasses water, and then put in the oven and baked until after scratching the skin the inside is thoroughly "rotten." Then another coat of wash, or two if necessary, may be given, and the core is redried. It is surprising how strong this skin becomes, and it is no more than one thirty-second of an inch thick.

In a great many cases a core has to stand much greater pressure than the mold itself, as, for instance, in a pipe or cylinder, where the metal is shrinking on the core from every direction. If the core is not collapsible one of two things must happen, — either it will crack the casting or the core will become so hard that its removal will be a very expensive and lengthy operation.

The second point, namely, the composition of the metal itself, is equally important with the foregoing. Any conditions which tend to hot shortness of the metal, which means brittleness above red heat, must be carefully avoided. The two principal elements found in common practice which have this tendency are sulphur and copper, and while their influence is not very great in the cold state of the steel, still, as the metal has to pass through the hot short period before cooling to the ordinary temperatures, it is important they should be kept as low as possible. Either

of them by itself is dangerous, but the combination of the two is fatal. As a large proportion of eastern iron is made from ores from the Cornwall district, a great deal of the scrap available, as well as the iron, has an appreciable content of copper, and it is therefore necessary to watch the sulphur most carefully, and care should be taken not to allow it to run over .045 per cent. This is done by selecting melting stock as low as possible and running a high manganese, which will prevent increase of sulphur from the coke, etc., and tend to reduce it, if anything, by the formation of sulphide of manganese.

COST OF PRODUCING STEEL CASTINGS BY THE OPEN-HEARTH PROCESS AND THE SMALL CONVERTER *

By L. UNCKENBOLT

THE small open-hearth furnace and the small converter are not really rivals, each having its proper field of action and suitable uses, and any attempt at replacing one by the other will prove an economic failure. A four- to five-ton open-hearth furnace for cast steel can only produce castings exceeding about half an inch in thickness and 1 cwt. in weight, without wasting three to four tons of the charge, the contents of the furnace cooling down so quickly during the casting that the steel becomes insufficiently fluid to run into small molds. Now the converter enables castings of any size to be made, and is particularly profitable when those of small dimensions (less than one-half inch thick and 1 cwt. in weight) are to be produced; in fact, Belgian foundries make, by its aid, castings of one pound weight and one-eighth inch thick, such as could only be obtained formerly with crucible steel, malleable castings, or the hydraulic press. However, it is not advisable to erect a steel plant solely for the production of small goods on which a large profit is made, the work of casting being in this case very complicated. In order to avoid this inconvenience, it is necessary to produce large articles as well, in a proportion that can easily be determined by experience.

The cost of a simple steel plant, with a single cupola capable of treating about three tons per hour, and a one-ton con-

* "Iron Trade Review," August 17, 1905.

verter, will be, for the cupola, £80; the fan, £20; the converter, £200; the blower, £100; the reheating furnace, £40; the drier, £40; the sand blast machine, £120; two drums and two mills, £40; several casting ladles and other accessories, £120; crusher and disintegrator, for sand £40; small pattern shop, £80; total, £880.

Should the business after a while entail an increase in the plant, the following additions could be made: a second drier, £60; a second reheating furnace, £60; an electric welder for repairing small superficial defects, £200; several grinding machines, £100; one or two cold saws, £60; a small chemical laboratory, £120; a testing bench, £80; total, £680.

To this outlay must be added the cost of buildings, source of motive power, a hoist, a platform for the cupola, a weigh-bridge for the yard, and a five-ton traveling foundry crane, the whole amounting to £2,000 to £3,000.

Statements have recently appeared in the German technical press to the effect that small converter steel plants can be erected at less than the above figures; but it is hardly probable that such plants would be able to compete with those already existing, it being essential to success to furnish consumers with a good article, quickly and at a low price.

The motive power required will be 5 to 10 horse-power for the fan, 5 horse-power for the hoist, 50 horse-power for the converter blower, 5 to 10 horse-power for the sand-blast machine, 10 to 15 horse-power for the drums, 5 to 10 horse-power for the sand-preparing machinery, and 3 to 5 horse-power for the pattern shop. Later on, this can be increased by 5 to 10 horse-power for working the converter, 30 to 40 horse-power for the electric welder and 10 to 15 horse-power for the saws, lathes, traveling cranes, planing machines and testing bench. It will not be necessary to keep all the machines working continuously. For example, to produce one ton of steel, the cupola fan is worked for half an hour, the converter blast half an hour, the converter mechanism three to four minutes, and the hoist five minutes. In this way, a 100 to 500 horse-power engine will be sufficient, though it is always better to have too much power than too little. A traveling crane of 5 to 7½ tons capacity is a prime essential, since it will enable all orders to be executed, even with only a single cupola and one converter.

The steel from the converter is at such a high temperature that several charges can be collected into a large heated ladle, so that very large castings can be produced when required. The author has made castings of 3 to 5 tons each in this way without difficulty.

The cost price may be calculated as follows: To obtain one ton of molten steel, as it issues from the converter, the materials required will be: 14 cwt. of Bessemer iron, at 56*s.* = 39*s.* 2*d.*; 4 cwt. of hematite pig, at 62*s.* 6*d.* = 12*s.* 6*d.*; $5\frac{1}{4}$ cwt. of scrap, at 44*s.* = 11*s.* 6*d.*; $\frac{1}{2}$ cwt. of complementary materials (ferro-manganese, ferro-silicon, ferro-aluminum) = 5*s.* 8*d.*; $4\frac{5}{8}$ cwt. of foundry coke, at 17*s.* 6*d.* = 4*s.* 2*d.*; $2\frac{1}{2}$ cwt. of gas coke for heating the ladles, drying the molds, etc., = 1*s.* 6*d.*; or, together, 74*s.* 6*d.*, as the cost of the ton of steel. From this quantity must be deducted 5 cwt. for waste in casting, and worth only the price of scrap (44*s.*), viz., 11*s.*, leaving 15 cwt. of steel costing 63*s.* 6*d.*, *i.e.*, 84*s.* 8*d.* the ton.

The cost has to be increased by the items for labor, upkeep and motive power, as follows: In respect of labor, there will be needed for an output of 25 tons, two men for the cupola, at 3*s.* 6*d.* = 7*s.*, and two for the converter at the same rate of pay, or 14*s.* in all, which works out at a little over 7*d.* per ton. With regard to the upkeep of the cupola and converter, a 1-ton converter working every day will usually give 60–80 pourings before needing repair. But assuming that it needs repair once a fortnight, and that during this period 50 pourings have been made, the refractory lining will cost £5 and the labor 14*s.*, which, together with 6*s.* for the repair of the cupola, makes £6 for an output of 50 tons, or 2*s.* 5*d.* per ton.

To produce 25 tons a week will entail the following outlay for motive power: 5 horse-power for $1\frac{1}{2}$ hours to work the hoist, costs $1\frac{1}{2}$*d.*; 10 horse-power for $12\frac{1}{2}$ hours driving the cupola fan, 2*s.* and 50 horse-power for an equal period, driving the converter blower, costs 10*s.* or 12*s.* $1\frac{1}{2}$*d.* in all, making in round figures 6*d.* per ton. The total cost of the ton of steel is, therefore, 84*s.* 8*d* + 7*d.* + 2*s.* 5*d.* + 6*d.* = 88*s.* 2*d.* This may seem high, but is an outside figure, having been obtained on the basis of an output of 20 to 25 tons per week with a plant consisting merely of one cupola and a single converter. Hence the cost would be considerably reduced in a plant with two converters,

since in the latter case a larger number of pourings could be made without interruption, thus greatly diminishing the outlay for coal and coke.

No doubt the objection may be urged that steel can be produced much cheaper in the open-hearth furnace, but it should be remembered that this furnace, when once started, must be kept going at all hazards, whatever the state of the market, a condition that will undoubtedly prove onerous in the long run. With the converter, on the other hand, work can be suspended when trade is bad and orders slack, so that no loss is being incurred, even if no profit is being made.

NEW OPEN-HEARTH STEEL PROCESS *

By P. ACKERS

SINCE the year 1865, the date of its appearance, the open-hearth process of steel manufacture has made enormous progress. From the 5-ton furnace built by Martin at Sireuil, to the 200-ton furnaces recently erected by Wellman in America and in England, there is a great step, almost unique in the annals of metallurgy. The Martin process owed its initial successes to the use of scrap and crop-ends from Bessemer steel works and mills; this success grew greater when it became recognized that the metal obtained in the open-hearth furnace was more regular and more definite in its composition than that obtained by blowing processes. From thenceforward Martin steel was employed in all special manufactures requiring a metal of specific chemical composition and manifesting definite mechanical properties. The process, as usually carried out, consists of charging a certain quantity of solid pig iron, and of completing the charge with scrap, the proportion of pig iron varying according to the heat of the furnace, the quality of the iron and the degree of hardness required in the steel.

This process, which permits of the requisite degree of purification being attained even with phosphoric pig iron and inferior scrap, takes a longer time the more phosphorus there is in the bath. Even with a pure pig iron requiring but a slight

* Read at the Mining and Metallurgical Congress at Liége.

degree of dephosphorization the production cannot be reckoned on exceeding 70 tons per 24 hours in a furnace of 15 tons capacity. This being so the cost of open-hearth steel is far higher than that of Bessemer or basic steel, but the advantage of the process lies in the fact that, provided the sulphur be low, a wide range of pig iron can be employed, whereas the other processes necessitate the use of pig iron containing definite amounts of silicon and of phosphorus, which prevents the use of many ores. Nevertheless, the manufacture of steel by the open-hearth process is slow, and only yields steel at more or less lengthy intervals and in large quantities at a time, which is a drawback from the point of view of securing a regular supply for the mills.

All new processes of open-hearth steel have as their object the avoidance of these disadvantages and the regularization, as far as possible, of the furnace outputs. One improvement that has been effected is the use of liquid pig iron, introduced straight from the blast furnace, into the furnace. This method is, however, only logically sound when a large proportion of the charge, say 75 per cent, is introduced in this way, under which conditions the decarburization of the bath will take even longer than usual unless it is hastented by the addition of some material which is more highly oxidizing than scrap, *i.e.*, iron ores.

Ore Process. — The method employed in this case is based on the old direct ore process, of which it is but a perfected outcome. It consists of charging the ore and the liquid pig iron together. The ore is charged first and heated in the furnace until the ladles of liquid pig are brought up and their contents poured into the furnace. The decarburization of the pig iron in contact with the mineral oxides takes place more rapidly than in the old process, and produces a violent reaction which hastens the end of the operation; in five hours from the time of charging, 25 to 30 tons of steel may be run out. The ores employed should be rich and easily reducible, and they should be in suitable-sized pieces, the presence of much fine ore occasioning the passage of much dust into the regenerators. The pig iron should have a suitable proportion of manganese; the presence of phosphorus, while delaying the operation, scarcely affects the ultimate result. The process also economizes a considerable quantity of fuel. The method was first practiced at Dona-

witz, and has spread rapidly since, being peculiarly adapted to districts where the available ores are too high in phosphorus for the Bessemer process, yet too low for the basic process. Silesia and Poland afford instances.

The following details relating to the practice followed at the Jurjewka Works, Donetz, were furnished by Mr. Sundgsen, the managing director.

There are five 25- to 30-ton furnaces supplied with metal from a 150-ton mixer. The metal shows the following average composition:

Silicon	Manganese	Sulphur	Phosphorus
1.0 to 1.5	2.25 to 3.0	0. to 0.3	0.15 to 0.25

Krivoi-Rog ore containing 65 per cent of iron and 0.10 per cent of phosphorus is used.

The results obtained at these works are remarkable. During July, 1904, 13,754 tons of good ingots were made on a working equal to 140 days, and 570 charges, or 98 tons per 24 hours per furnace. A 20 per cent saving of coal was effected. The average composition of a charge was 25,724 kg. of liquid iron and 176 kg. of ferro-manganese; 6,240 kg. of ore and 2,400 kg. of fluxes. The working of the charge occupied $5\frac{1}{2}$ hours from charging to tapping. The composition of the pig iron used and of the steel obtained were as follows:

	C	Si	Mn	S	Ph
Pig iron	4.25	1.17	2.80	0.03	0.20
Steel	0.07	0.01	0.50	0.03	0.04

Five thousand kg. of slag were produced containing:

Si	Mn	S	Ph	Fe	CaO	Al_2O_3	MgO
24.8	14.40	0.14	0.46	8.10	35.55	1.80	9.7

This corresponds to a loss of iron equal to 405 kg. The ore, however, yielded 4,056 kg. of iron, so that the gross gain of iron equaled 3,651 kg. The loss on metalloids, manganese, etc., amounted to 2,020 kg.; hence, 3,651 minus 2,020 represents the actual yield over the weight of pig iron charged = 1,631 kg., which is equivalent to a yield of 106 per cent.

The furnaces at Jurjewka resemble in all respects ordinary basic open-hearth furnaces of 25 to 30 tons. When the liquid pig iron is first charged into the furnace on to the ore, there is a very violent reaction. When the boil becomes too strong, the

air and gas are temporarily cut off and other precautions are taken. It is necessary that the gas ports should be fairly long in such furnaces, and that the angle at which they enter the furnace should be sufficient to prevent slag finding its way into the regenerators when the reaction becomes too intense. At Jurjewka the angle is about 30°, and the length nearly 10 ft. While the process effects various economies in cost as compared with that usually employed, it has one disadvantage,— the difficulty of regulating the supply of pig iron from the blast furnaces to the mixer, arising at times from the simultaneous tapping of two blast furnaces, or the simultaneous charging of two or more steel furnaces.

The Bertrand-Thiel process of steel production entails two distinct operations and the employment of two furnaces or sets of furnaces. It depends on the following considerations. If liquid pig iron is brought into contact with less ore than is required to oxidize its impurities a rapid reaction occurs, and the pig iron exhausts the oxidizing capacity of the ore, with the production of an inactive slag and the reduction of a large proportion of the iron in the ore. If, on pouring off this slag, a fresh quantity of ore be charged, the reaction will be very intense because of the excess of oxygen present, and the time will be proportionally hastened.

The process is carried out in two furnaces. In the first the quantity of ore is deficient, and the metal after the reaction is run into the second or finishing furnace, where the ore previously heated is in excess. It must be so adjusted that the length of time taken in the two operations should correspond, in order to insure continuous working. The process is based upon rational principles, inasmuch as the conditions are such as to favor dephosphorization at the lower temperature of the primary furnace, and decarburization takes place at the higher temperature of the secondary furnace. The slag from the primary furnace, being richer in phosphoric acid, is of greater value for agricultural purposes. The details of the process have often been described. The author considers that when conditions admit of obtaining cheaply a pig iron containing little silicon, from 1.7 to 2 per cent of phosphorus, 1.5 to 2 per cent of manganese, and where a large production is desirable, the basic-Bessemer process is to be preferred, as being less costly.

Dual processes have their uses when local circumstances require the treatment of pig iron too high in silicon for basic processes and too high in phosphorus for acid Bessemer practice. A typical system, which must, however, be regarded as a makeshift, is that in which the pig iron is partially refined in an acid converter and finished in a basic open-hearth furnace. It has been employed at Sosnovice.

The Talbot Process. — This consists of working down a charge in the ordinary way, withdrawing 25 to 35 per cent of the bath into a ladle where it is recarburized and tapped, and filling the furnace up with liquid pig iron. The bath then consists of fluid metal, the carbon percentage of which has been already lowered, and, on the addition of molten pig iron, the strong reaction occurs. This reaction is stronger in proportion as the difference between the amount of carbon in the added metal and in the bath is greater, and hence hastens the operation, and renders it much quicker than the ordinary Siemens-Martin process.

The furnace employed is a tilting one of the Wellman type, and is too well-known to need detailed description. It is somewhat costly, amounting to £20,000 for a 100-ton furnace, but as this estimate includes the cost of charging appliances and accessories which can serve several furnaces, it may be more correctly estimated at about £14,000 per furnace. The process is in operation in America, at Pencoyd, where it originated, and where the first furnace of 160 tons capacity made a weekly output of about 1,300 tons. It has also been introduced at Frodingham and at Cardiff.*

The Talbot process yields a more regular and larger supply of steel than the ordinary method, although its first cost is greater. It is economical from a fuel consumption point of view, and the steel made is cheaper than ordinary Siemens steel, although not so cheap as Bessemer steel. A disadvantage of the process is the difficulty of making hard steel by it. The steel can, it is true, be recarburized to any desired extent in the ladle, but the method is uncertain owing to the losses of coke, which cannot with certainty be controlled.

The modified Talbot process is in operation at Czenstochowa,

* It will also be adopted at the reconstructed Cargo Fleet Ironworks. (Note by translator.)

and was described in a paper by M. Surzycki, read at the recent meeting of the Iron and Steel Institute. It seems to possess the merit of being economical, but at the same time shares the disadvantage already pointed out with regard to the homogeneity and quality of hard steel. It is difficult to regulate the amount of metal tapped, and hence to determine with accuracy the necessary amounts of material to be added to recarburize.

Conclusions

The following broad conclusions may be drawn:

Charging open-hearth furnaces with liquid pig iron is so convenient and economical that there is no doubt it should be adopted, and that with this view new open-hearth plants should always be erected in the vicinity of blast furnaces. The advantages arising from this selection of site are:

1. Economy of labor in handling the output of the blast furnaces and in charging the steel furnace.

2. The time of working a charge being diminished by using liquid pig iron, production per furnace can be increased.

3. Manufacture of steel is independent of the quality or cost of scrap, of which the percentage proportion per charge can be adjusted to suit the supply.

4. The steel works can reap the advantage accruing from the use of the waste blast-furnace gases for power purposes.

5. The fuel economy is considerable.

When ores containing not too much phosphorus are available, as at Jurjewka, the ordinary process of charging liquid pig iron may be followed; with ores higher in phosphorus, but containing less than 1.8 per cent, the Bertrand-Thiel process may be tried; when a mild steel is required, the Talbot and Surzycki processes give good results. As long, however, as ores — and, consequently, pig iron — high in phosphorus are found abundantly, open-hearth processes in general will have a worthy rival in the basic-Bessemer process.

THE CLEANING OF BLAST-FURNACE GAS*

By AXEL SAHLIN, London

THE rapid development of the gas-motor during the last five years has given new value and importance to the gas escaping from the blast furnace, previously often described as waste gas. This "waste gas" has now become a potential source of energy, which, rightly used and husbanded, should, together with the gas from the coke-ovens supplying the blast furnaces, suffice for the carrying out of the entire series of converting and finishing processes which transform the ore into marketable steel products.



The gas leaving the blast furnace carries with it a varying amount of gritty dust, which has proved a more serious obstacle to the successful operation of large gas engines than any mechanical imperfection in the construction of these engines.

Successful efforts to remove the dust from the gas used in the gas engine have, in a practical manner, demonstrated how wasteful and imperfect have been our previous methods of utilizing the valuable blast-furnace gas.

Until the appearance of the gas engine at the blast-furnace plant the dust problem was, as a general rule, dealt with in a different manner by each of the three large iron-producing countries.

In England, in at least 90 per cent of the blast-furnace works, the dust in the gas was disregarded. A single downcomer carried the gas escaping from the tunnel-head into an underground gas-flue leading to stoves and boilers. In this flue and in the stoves and boilers the bulk of the dust was deposited. Every few months a rather long stoppage, regularly attended

* Read at the May, 1905, meeting of the Iron and Steel Institute.

by subsequent more or less costly disturbances of operation, was required for the cleaning of these flues, while the cleaning of stoves and boilers belonged to the daily routine of the works. English engineers were in a position to ignore the dust problem, partly because of the customary slow driving, and partly because of the clean and firm structure of the materials used. But even with these advantages, stoves, and especially boilers, had often to be put out of operation, cooled down and cleaned, and the efficiency of the plant suffered.

In Germany the majority of the furnaces were equipped with a dry or wet dust-catcher, consisting of a series of upright tubes of small diameter, the open bottoms of which extended downwards into a common water-seal. The dust was deposited mostly by centrifugal force, as the direction of the flow of the gas was suddenly changed in passing through the cross tubes connecting one chamber with the other. Usually six of these chambers from 6 feet to 8 feet in diameter, and often 60 feet in height, constituted the dust-catcher. The collected dust was raked from the pan forming the water-seal by manual labor. The gas leaving the dust-catcher could not be considered properly cleaned.

Since the discovery of the Mesabi mines American blast-furnace engineers have been compelled to use a burden containing from 50 to 100 per cent of dust-fine ore, and the question of cleaning the gas became one of imperative importance. The generally adopted American dust-catcher consists of a wide, unobstructed chamber, through which the gas passes and in which its velocity is greatly retarded. The bottom of the dust-catcher is built as a hopper, closed at its lowest point by a door or valve, through which the dust from time to time is removed by gravity.

It required the appearance of the gas engine to compel improvements in these methods, and to stop, at least partly, the waste which we all complacently had permitted to go on from year to year.

We have now learned and realize that the whole of the gas escaping from the blast furnace should be utilized for subsequent refining and finishing processes, and that, before being so used, it should be thoroughly cleaned.

By cleaning all the gas we would save:

1. One stove per furnace. No reserve will thenceforth be necessary to maintain the capacity of the furnace during the periods of cleaning of the different stoves, and three stoves per furnace will give good practice.

2. The heating surface of the three remaining stoves may be made 10 per cent smaller than hitherto, because, with dusty gas, the value of the heating surface will gradually decrease, whereas with clean gas it will have a permanent efficiency.

3. The heating surface of the boiler plant may be reduced from 10 to 15 per cent for the same reason, and because the necessity for periodical cleaning of the boiler settings will disappear.

4. The repairs to the boiler plant will be reduced as the strains due to frequent cooling of the boilers are avoided.

5. The labor force previously constantly employed in cleaning stoves and boilers may be dispensed with.

6. The more perfect combustion will reduce gas consumption and liberate for use in other departments a considerable percentage of gas hitherto wasted. The percentage of gas thus saved may be estimated at about 20 per cent of the volume burned in stoves and boilers.

7. The success of blast-furnace operations depends entirely on the regularity and uniformity of conditions affecting the furnace. Uniform fuel gas will give uniform heat and uniform power, and will add increased efficiency to the furnace, which we all recognize, though it may not be easy to express the gain in exact figures.

Assuming, then, as an understood and accepted axiom, that blast-furnace gas should be cleaned before being burned, we proceed to consider the process of cleaning from two points of view: (1) The degree of purity reached, and (2) the cost of reaching it.

It is the removal of the last fraction of a gram of dust contained in a cubic meter of gas which largely adds to the expense of cleaning. For stoves, boilers, kilns, furnaces, etc., such a small quantity of exceedingly fine and buoyant dust is no detriment, as it will pass off with the products of combustion through the smoke-stack. A gas containing 0.3 gram per cubic millimeter, or less, is sufficiently clean for these purposes.

For the gas engine, on the other hand, the gas can never be too pure, and the removal of the last tenth of one gram, though expensive, will pay for itself in longer life and decreased repairs to the expensive engines.

The cleaning of the blast-furnace gas should, therefore, take place in three stages, as follows:

1. The preliminary dry cleaning, which does not involve extra operating expenditures.

2. The wet cleaning to fit the entire quality of gas for use in stoves and under boilers, in roasting kilns, furnaces, etc.

3. The special cleaning for purifying part of the gas for power purposes.

1. *Dry Cleaning.* — The gas should be removed from the blast furnace as much as possible symmetrically around the circumference of the furnace, so as to avoid an excessive flow of gas in any one direction. The use of four gas uptakes, which, curving downwards, should unite into one main downcomer, is to be recommended; this downcomer to enter the dust-catcher tangentially and near the bottom of the chamber. It is a mistake, from the point of view of cleaning, to make the downcomer too wide. It should be designed so as to cause the gas to flow with an average velocity of from 25 to 35 feet per second. The dust-catcher should be built in the shape of a vertical cylinder with conical top and bottom; it should have a diameter of not less than four times that of the downcomer. The delivery opening from the dust-catcher should be placed centrally at the top of the same. The gas will, by this arrangement, on entering the dust-catcher, be given a rapid swirling motion, and the two powerful and inexpensive agents, gravity and centrifugal force, will combine to deposit in the dust-catcher all the heavier particles of dust. According to the nature of the materials charged, the dry dust thus collected may, or may not, be worth briquetting and recharging.

The gas leaving a well-designed dust-catcher may still contain from 2 to 8 grams of dust per cubic meter, depending largely on the character of the ore employed and the rate of driving of the furnace.

The whole volume of gas should next be submitted to the second stage of the cleaning process.

2. *Wet Cleaning.* — The second cleaning should be effected

by means of water. Experience has proved that the fine dust settles most readily on cool and moist surfaces. The passage of gas through open chambers, even though profusely sprayed with water, has not proved effective.

Inventive effort has, during the past five years, been directed towards providing gas-cleaning apparatus, which may be grouped into three classes:

(*a*) Stationary cleaners or scrubbers.

(*b*) Rapidly revolving or atomizing machines.

(*c*) Slowly revolving or fresh contact cleaners.

(*a*) *Stationary Cleaners.* — These consist of chambers from the top of which sprays of water, distributed over the entire section of the chamber, descend. The water is arrested by a number of grids or porous masses of material with numerous interstices. Iron bars, rolled and cast, tangled wire, coke or wooden slats, have all been used with success as filling material or grids. The gas enters the apparatus from below the grids and ascends, meeting the sprays of water falling from above through the innumerable interstices in the obstructing grids or masses, to the wet surfaces of which the dust adheres, only to be washed away by the falling drops of water. The Zschocke cleaner is a well-designed type of such apparatus. It is claimed that the gas leaves this apparatus with from 3.0 to 1.4 grams of dust per cubic meter.

(*b*) *Rapidly Revolving Machines.* — The earliest form of the rapidly revolving or atomizing apparatus was, as a matter of course, the fan. Having been in use for generations, it was at once available as a mechanically perfect tool. The water injected into the fan, together with the gas, was forcibly dashed against the casing, removing the dust.

A modification of the fan is the Theisen apparatus, which provides a forced contact between gas and spraying water driven against a cylindrical envelope by fan blades set at oblique angles to the axis of rotation.

There are probably no more effective contrivances known to-day for elimination of the last fractions of a gram of dust per cubic meter than a properly designed and rapidly revolving fan or a Theisen apparatus. But the good work is not done cheaply, as the power consumed for revolving the blades increases greatly when the water sprays are put in operation.

This class of apparatus is, therefore, most suitable for thoroughly cleaning the portion of gas used for generating power.

(*c*) *Slowly Revolving Apparatus.* — The considerable power required to drive rapidly revolving water-sprayed fans, on the one hand, and the difficulty of insuring a thorough and uniform cleaning of the grids or checkers of the stationary apparatus on the other hand, led to the design of slowly revolving gas cleaners, which are particularly suited for the second, or wet, cleaning of the entire volume of gas produced by the furnace before it is admitted to the stoves, boilers, kilns, or to the fans which finally prepare it for the gas engines.

The Bian apparatus is the earliest form of this type, and has proved very effective. It consists of a horizontal cylindrical casing, through which the gas is passed from end to end. In the axis of the cylinder revolves slowly a shaft, to which are bolted a number of circular disks of perforated plates of a diameter but little less than the inside diameter of the casing. The gas is, therefore, in its progress compelled to pass through the perforations in the disks. Between the perforated disks extend from the outer envelope annular deflecting plates, which compel the gas to approach the center of the apparatus after each passage through the perforations in the revolving disks. The outer shell is filled with water up to the bottom of the central shaft. In revolving the perforations in the disks are therefore dipped into water and thoroughly washed for every revolution of the apparatus, and ascend from the bath covered with thin films of water. The dust which settles on the bottom of the apparatus is from time to time drained off through suitable sludge valves.

This apparatus is effective, and requires but little power slowly to revolve the central shaft and the disks fastened thereon.

With the view of securing larger capacity of each apparatus (that is, a larger area of perforations in proportion to the diameter of the apparatus), a better and more continuous wetting of the perforated surfaces and a more automatic and constant removal of the dust, my firm have designed a new style of slowly rotating gas-cleaning apparatus, which has been named the Sahlin revolving gas-cleaner, shown by Fig. 1.

It consists, like the Bian apparatus, of a horizontal cylindrical shell. Parallel with the axis of this shell, but somewhat

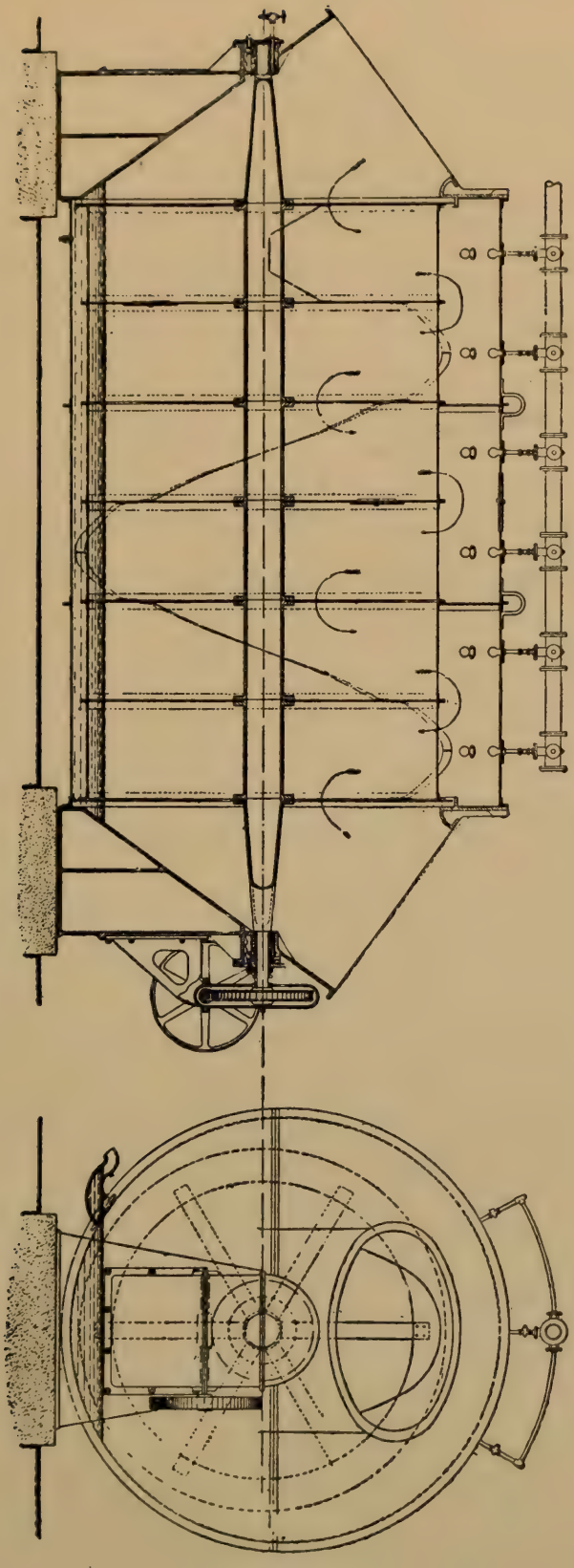


FIG. 1

below the center of the same, is placed a horizontal shaft. On this shaft are fitted, alternately, spider arms supporting rings of double 3-inch angle iron riveted together, and solid plate disks carrying at their circumference similar angle rings. Between the angles of the spider arms and those of the disks are bolted perforated plates forming the envelope of a drum. The oblong perforations are wider at the end of the cylinder where the gas enters, and gradually narrower towards the discharge end. Between the outer shell and the inner revolving drum is formed a horseshoe-shaped space, widest at the top. Closely behind the rim of each spider, this space is divided by plate diaphragms riveted to the outer shell, and practically closing the open area between shell and drum. To the angle rings of the frame, supported by the spider arms and by the disks, are bolted a series of spirally bent flat bars, or scrapers, which closely approach the bottom of the shell. Near the gas inlet is riveted to the lower part of the shell a water-sealed discharge opening. At the bottom of the shell, near the gas entrance, a drain-cock or sludge valve is provided for emptying the apparatus. Along the top of the shell three rows of sprinklers are arranged, so as to deluge the entire top of the revolving perforated plates with a dense spray of water. The drum is turned by worm and worm gear through a belt pulley driven from the ventilator described below.

When gas enters the apparatus through the head of the outer shell, it is admitted into the drum between the spider arms supporting the first angle iron ring, but is then confronted by the first solid disk. The only passage offered is through the narrow and dripping perforations of the drum. In passing these, the gas is met by the profuse spray from the sprinklers. It is at the same time spread out into a thin sheet in the horseshoe-shaped space between the two cylinders, and advances outside and beyond the first revolving disk until met by the first horseshoe-shaped diaphragm, which prevents further progress and compels the gas again to enter the interior of the drum beyond the first disk. Passing through the openings in the second spider wheel, it is again compelled to flow outward through the perforations in front of the second disk, and so on, the gas passing forward and back through the perforated envelope, now spreading itself into a thin layer, now contracting itself into a cylindrical column, and continuously exposed to the intense spray

from the sprinklers. The gas has, of course, to turn an angle of 180° for every time it passes through the perforations. It is finally delivered through the discharge opening, which corresponds to the opening of admission, at the opposite end of the shell.

The dust is settled in the water at the bottom of the shell and is moved by the spirally-bent scrapers towards the inlet end, where it is discharged automatically through the water-sealed overflow.

As the areas of drum, perforations and horseshoe-shaped space are all very large, compared with the section of the downcomer, the velocity of the gas in passing through the apparatus is greatly reduced. The resistance offered by the apparatus is, therefore, insignificant, even though the entire volume of gas produced by one furnace is passed through a single apparatus.

The perforated drum is revolved about six reversions per minute, requiring less than $1\frac{1}{2}$ horse-power, which power is transmitted by a belt from the shaft of the ventilator.

It has been found that whether a stationary or slowly revolving apparatus is used for the second cleaning, the tunnel-head pressure must be assisted by a ventilator, to insure an even flow of gas. This ventilator is, however, by no means as great a consumer of power as would be water-sprayed cleaning fans or atomizers. A ventilator passing 40,000 cubic feet of gas per minute (equal to about 70,000 cubic meters per hour) against a head of 2 inches water column, requires only about 35 horse-power.

Safety Device. — If for any reason, such as the hanging of the furnace or the sudden stoppage of the blowing engine, the flow of gas from the furnace should cease or be reduced, there is with all forms of gas-cleaning apparatus a danger that air may be drawn into the apparatus and gas tubes, where the mixture of gases formed may, in unfavorable circumstances, cause serious explosions. To prevent the possibility of this, I recommend a very simple and effective device, consisting of a small gasometer having a diameter of 8 feet, with a lift of 6 inches. This gasometer is so balanced that it will drop when the pressure inside the piping falls to $\frac{1}{4}$-inch water column.

The interior of the gasometer is connected by a pipe with the dry dust-catcher. An arm projecting from the top of

gasometer connects with a switch in the circuit carrying the electric current to the motor driving the ventilator and cleaner in such manner that, when the gasometer drops, the current is broken and the motor stopped. When the returning pressure in the dust-catcher causes the gasometer to rise, the circuit is automatically closed and the cleaning apparatus started.

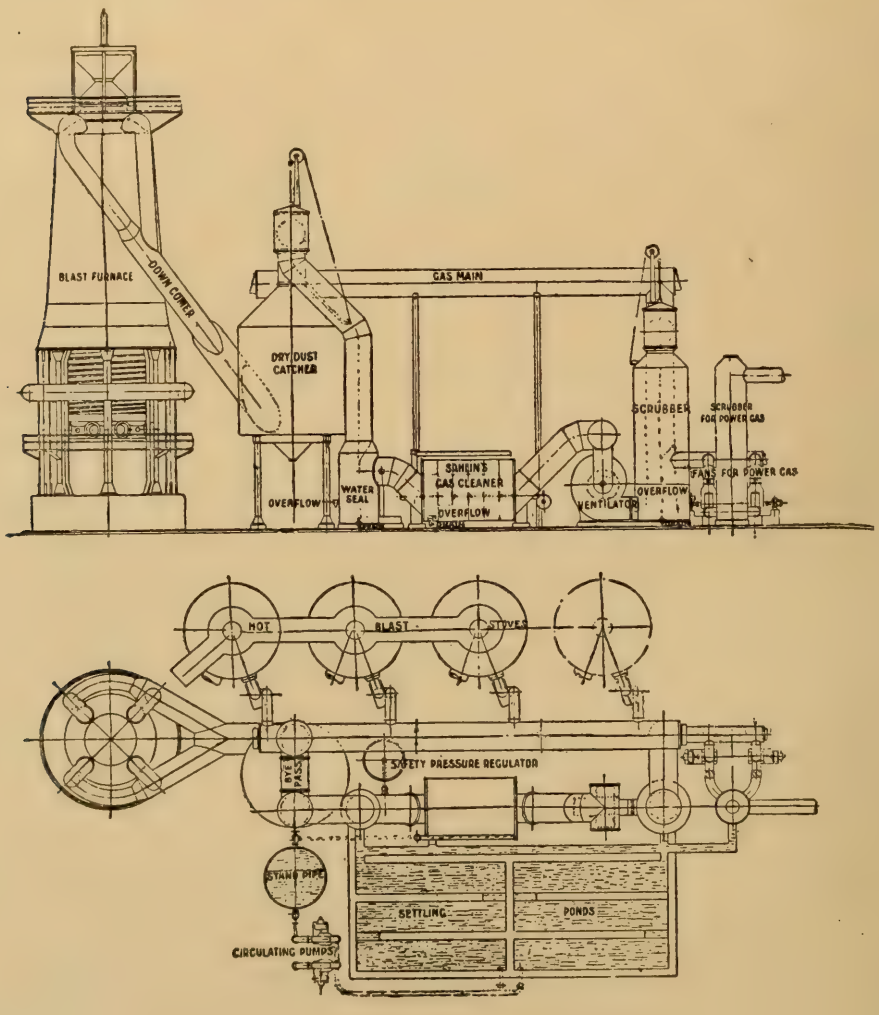


FIG. 2

A general outline of a cleaning plant for the entire volume of gas from one blast furnace is shown by Fig. 2.

The gas leaves the furnace through four uptakes placed at 90° angle. These join into one downcomer, which delivers the gas in tangential direction into a cylindrical dust-catcher. From the top of the dust-catcher the gas passes through one

of two mushroom valves. The valve nearest to the stoves connects the dust-catcher direct with the gas main, and is opened only in case of repairs to the gas-cleaning plant. The second valve connects the dust-catcher with a water seal, from which the gas flows into the Sahlin gas cleaner described above. From this gas cleaner it reaches a ventilator which delivers the now sufficiently clean and cooled gas into the bottom of a dryer. By closing the drain pipe and admitting water, this scrubber or dryer may be changed into a second water-seal, effectively isolating the cleaner. Crossbars inside the dryer carry a column of coarse coke. In passing through this the gas is freed from the bulk of the water which may be mechanically carried from the second or wet cleaning. At the top of the dryer a mushroom valve again admits the gas into the general gas main. There is no spare or reserve provided for this simple wet gas-cleaning plant. The damage caused by occasionally, for short periods, using gas direct from the dust-catcher, as now is being done continuously, is not sufficient to justify an increased investment in duplicating the plant.

The power required for the second stage of cleaning of 40,000 cubic feet of gas of a temperature of 20° C. is, as above stated, 36½ horse-power, to which must be added 8 horse-power for pumping of cooling water.

3. *Gas for the Power Plant* is drawn from the clean gas main and is passed through one of two electrically driven fans sprayed with water and discharging into a second smaller dryer, whence the gas, now, practically speaking, dust free, is sent to the engines. The size of this plant depends on the quantity of gas required for power purposes. A fan cleaning 10,000 cubic feet per minute, and using 8,000 gallons of spraying water per hour, requires about 65 horse-power, and will supply gas engines of from 5,000 to 6,000 horse-power. The pumping of spraying water will require about 3 horse-power additional.

The cooling water used in the cleaning processes is delivered into double settling and cooling ponds, and is thence lifted by centrifugal pumps into a standpipe or water-tank, from which it is returned by gravity to the cooling plant. On top of the tank may be arranged trays for additional cooling of the water.

Slightly modified, as shown by Fig. 3, the secondary cleaning plant may be attached to any existing gas main. A slide

valve is inserted into the gas main, and on either side of this valve is placed, on top of the main, a mushroom valve. The mushroom valve on the side nearest the furnace will connect directly with the water-seal and the Sahlin gas cleaner. The mushroom valve on the side away from the furnace will return the gas directly from the dryer into the existing gas main. Should it be necessary to stop the gas-cleaning plant, the slide

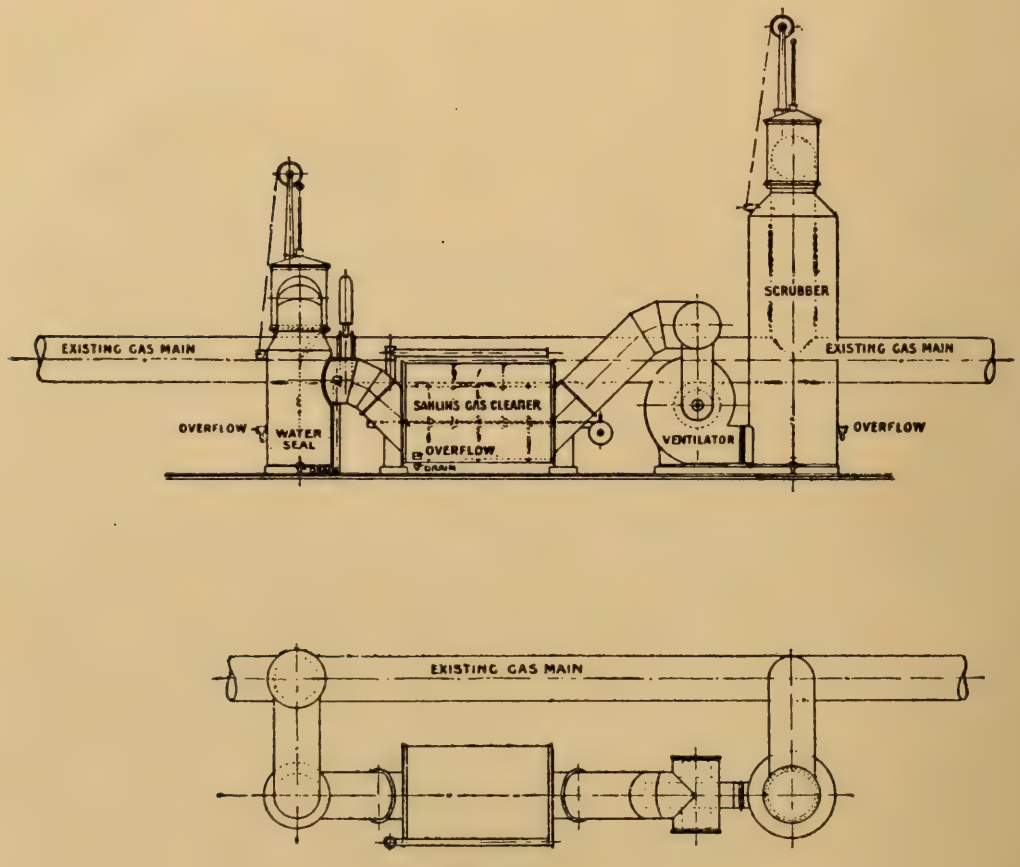


FIG. 3

valve is lifted and the mushroom valves are closed, the gas, according to present general practice, passing directly from the dry dust-catcher to stoves and boilers, or to the special cleaning plant for the gas engines.

Interruptions in the working of the secondary cleaning plant will, however, be infrequent, as the simplicity and solid construction of the plant will reduce repairs to a minimum.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

MICRO-METALLOGRAPHY with Practical Demonstration. J. E. Stead. "Journal of the Royal Microscopical Society. 7,500 w., illustrated. — In the first part of this paper the author describes the technology of metallography while the second part is devoted to a description of methods for detecting the more highly phosphorized portion of iron and steel. The following are abstracts from this paper:

Methods for Detecting the more Highly Phosphorized Portions in Iron and Steel. — On reading the published researches of micro-metallographers it would appear that very little attention has been paid to the methods for detecting or identifying the more highly phosphorized portions in iron and steel. I have, however, repeatedly had occasion to report upon the structure of steels and to draw attention to irregular distribution of phosphorus.

I have already published the methods of detecting phosphide in pig irons by the microscope; and it only remains for me to describe other methods for differentiating between the portions higher and lower in phosphorus in commercial irons and steels.

The following are detailed directions for applying the several methods:

Heat Tinting Methods. — When polished iron or steel is heated in air the surface becomes colored by the formation of

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* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

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films of oxide of iron. In proportion as the temperature is raised, or continued at one suitable temperature, the tints pass from pale yellow to yellow, brown, purple, blue and steel gray, and through the same series of tints a second time if the heating is continued, but the tints of the second series are not so intense as those of the first.

Massive carbide of iron becomes colored less rapidly than iron and more rapidly than phosphide of iron, whilst iron containing phosphorus in solid solution colors more rapidly than pure iron or iron containing less phosphorus.

Method 1. — Into an iron crucible or ladle, or other suitable receptacle, is placed about 4 ounces of tinman's solder(2 tin, 1 lead). The vessel is placed over a Bunsen burner and the solder melted. Into the metal a Le Chatelier couple, covered with a thin piece of asbestos paper, is inserted. The flame of the burner is adjusted until the temperature of the metal stands at 250° C. The specimens, having been polished, are rubbed with a piece of clean woolen cloth, and are warmed on a hot plate, or in a boiling-water oven, and when still warm they are again rubbed with the cloth. They are then floated on the molten metal. The reason for first gently heating is to prevent condensation of acid water from the waste products of the burning gas. If the precaution is not taken the specimen after heating will be covered with minute colored dots due to condensed steam. The surfaces of the specimens are watched and examined with a strong magnifying glass. They will assume a regular yellow tint, and in a few minutes the phosphorized portions will become brown on a yellow ground, and if the heating is continued they will become colored blue, whilst the parts not so high in phosphorus will be brown or dark yellow. At this point the specimens are removed and may be examined under the microscope whilst still hot. If the tinting is not sufficiently advanced they may be returned to the bath for further heating.

Method 2. — Instead of regulating the temperature of the bath it may be heated until the surface of the solder begins to form yellow films. Each specimen, preferably of the dimensions 20 mm. by 10 mm. by 5 mm., is, after warming and rubbing with a cloth, held at one end with a pair of tongs, and the under surface of the other end is immersed in the highly heated metal. In one minute or less the tinting will be complete, but

it will be graduated in color between gray at one end and pale yellow at the other; the intermediate part passing through the whole gamut of coloring. The specimens are removed when the central parts have assumed a brown color.

Treated in this way the phosphorized portions will be dark brown on a yellow ground, or blue on a brown ground.

Method 3. — The specimen is heated rapidly until uniformly blue, and when cold is immersed in water containing a one-thousandth part of nitric acid. The films covering the phosphorized parts will be dissolved in advance, and if the acid treatment is stopped at the right moment it is possible to have white phosphorized areas on a brown or blue matrix. This method gives very satisfactory results, but many failures to obtain the exact development may follow the first attempts. It is sometimes advisable to rub the developed specimen with moistened chamois leather before drying with a hot blast of air.

Method 4. — Instead of floating the specimens on the surface of liquid metal, they are placed in a jacketed copper chamber 4 inches in length and 1 inch square, which is surrounded, excepting at one end, with heavy mineral oil, maintained at a temperature of 245° C. A drawer is fitted into this, and into it the metal sections are placed. The tinting by this method of heating is more under control than by the first described, and it is easy to locate the parts highest in phosphorus even in steel castings containing under .05 per cent of that element.

Iodine Etching. — This method is based on the fact that a very dilute tincture of iodine in potassium iodide corrodes the portions lower in phosphorus relatively more rapidly than those containing more of that element.

The necessary reagent contains 1 gram of iodide and .01 iodine per 500 c.cm. alcohol and 50 c.cm. water.

The polished specimens are immersed in this and are examined from time to time. When it is seen that some portions remain brilliantly white on a dull ground, they are removed, washed with water and alcohol, and dried in a current of hot air.

In longitudinal sections of rolled steel after this treatment there will be seen white lines which may or may not be independent of the ferrite and pearlite areas. These white lines con-

tain the higher proportion of phosphorus. Relatively they resist the corrosive action of the iodine. That this is so may be verified by a longer action followed by slight re-polishing on wet parchment, when, even with the aid of a simple lens, the resist lines will be seen to stand in relief. When examined under oblique light rays, the phosphorized parts appear black on a light ground.

Picric Acid Etching and Tinting Method. — The long-continued action of a 2 per cent solution of picric acid in water containing 5 per cent alcohol will color the portions higher in phosphorus, yellow, brown, blue, etc.

This method is well adapted for the study of wrought iron and soft steel.

When applying the reagent the specimens are immersed in the solution.

The coloring may take several minutes to develop. When it is considered advisable to remove the specimens, they must be washed with water and alcohol, dried in a current of hot air, and on no account must they be wiped with a cloth, for the slightest friction is liable to remove some of the films.

A simple solution of picric acid in water colors the phosphorized portions in advance of the parts containing less phosphorus, but all parts will eventually become brown if the action is continued long enough.

Nitric Acid Etching and Tinting Method. — This method is based on the observation that very dilute nitric acid, like iodine, acts relatively less rapidly on the phosphorized portions, and at first they remain bright, but, if the action is continued, they become darkened by the formation of a dark-colored skin or film. This film is probably of the same substance as the black residue which remains when phosphorized steels are dissolved in dilute sulphuric acid.

On etching longitudinal sections of steel and iron, the phosphorized lines at first resist the acid and appear white on a dark ground, but after longer action the white lines become relatively darker than the less phosphorized parts — indeed, it is possible with care to obtain a positive and negative appearance on the same specimen by a short or more prolonged etching.

After strong etching, if the specimen is repolished on a cloth block, the phosphorus lines will stand in relief, and as the

dark stain is readily removed by slight friction, the lines appear white on a dull ground.

Professor Heyn has kindly sent me some photographs of steel structures developed by his copper-ammonium-chloride reagent, which appeared to be identical with those developed by iodine. Although he does not describe them as other than indicative of primary crystallization, I have but little doubt that they are mainly evidence of imperfect distribution of phosphorus.

If steel, containing low carbon, say under .5 per cent, in either the cast or forged condition, is very slowly cooled, the highly phosphorized areas reject the carbon which has segregated with the phosphorus, and as a result massive areas of ferrite appear, the borders of which are often surrounded with pearlite.

If the phosphorus is greatly concentrated in certain parts, carbon will not be retained there even on comparatively rapid cooling from a high temperature. **No. 413.**

Corrosion of Boiler Tubes. Rear-Admiral John D. Ford, U. S. N. "Journal of the American Society of Naval Engineers." 10,000 w., illustrated. — In this report the author describes the results of his investigation to ascertain the rate of corrosion of steel and iron boiler tubes. According to direction from the Bureau of Steam Engineering of the Navy Department the tests were made in twelve tanks, each tank containing sixteen samples from top, middle and bottom of steel ingots. The samples were shifted in their position each week, so that at the end of a period of sixteen weeks each sample had occupied consecutively every position in the tank in which it was placed, and at the end of each such period the samples were taken from the tanks, cleaned with a brush (but not scraped), washed, dried, weighed and photographed. The present report is based upon the results obtained at the expiration of the first, second, third and fourth periods of sixteen weeks. The tests were conducted in a room adjoining the chemical laboratory of the National Tube Company, that company having offered to furnish the tubes and give freely all necessary facilities and assistance. Both cold- and hot-drawn tubes were tested. The average loss in grams after each period of sixteen weeks is given below:

AVERAGE LOSS IN GRAMS

Class of tube	After 16 weeks (1st 16 weeks)	After 32 weeks (2d 16 weeks)	After 48 weeks (3d 16 weeks)	After 64 weeks (4th 16 weeks)
(1) Hot-drawn seamless steel...	.3034	.5333	.3510	.5070
(2) Lap-welded Bessemer steel.	.3147	.4950	.4043	.4945
(3) Cold-drawn seamless steel..	.3268	.5795	.4595	.5076
(4) Charcoal iron.....	.3326	.5896	.3966	.4893

The difference in the amount of loss in the four classes of tubes is not great, that of the charcoal-iron tubes, which had the greatest loss, being, roughly, 6.3 per cent more than the loss of the hot-drawn seamless tubes, which suffered the least.

Considering the three grades of the hot-drawn seamless tubes alone, it was found that the average losses per square inch of surface area were:

	After 16 weeks (1st 16 weeks)	After 32 weeks (2d 16 weeks)	After 48 weeks (3d 16 weeks)	After 64 weeks (4th 16 weeks)
Tubes from the top of ingot....	.3205	.5700	.3708	.5213
Tubes from the middle of ingot.	.3121	.5339	.3571	.5108
Tubes from the bottom of ingot	.2776	.4960	.3254	.4906

The difference in the losses of these three grades is very marked. At the end of the first sixteen weeks those from the top of the ingot lost 15.4 per cent more, and those from the middle of the ingot 12.4 per cent more, than those from the bottom of the ingot. At the end of thirty-two weeks those from the top of the ingot lost 14.9 per cent more, and those from the middle of the ingot 7.6 per cent more, than those from the bottom of the ingot. At the end of forty-eight weeks those from the top of the ingot lost 15.9 per cent more, and those from the middle of the ingot 9.7 per cent more, than those from the bottom of the ingot. At the end of sixty-four weeks those from the top of the ingot lost 6.2 per cent more, and those from the middle of the ingot 4.1 per cent more, than those from the bottom of the ingot; the loss from the bottom samples being less, probably, on account of the lesser amount of impurities and greater density of the metal of the ingot in this part.

Of the three grades of lap-welded Bessemer tubes the average losses per square inch were:

	After 16 weeks (1st 16 weeks)	After 32 weeks (2d 16 weeks)	After 48 weeks (3d 16 weeks)	After 64 weeks (4th 16 weeks)
Tubes from the top of ingot....	.3686	.5268	.4112	.4966
Tubes from the middle of ingot.	.2941	.4826	.3939	.4891
Tubes from the bottom of ingot	.2814	.4756	.4079	.4977

The difference here is even more marked for the top of the ingot than in the case of the hot-drawn tubes. At the end of the first sixteen weeks those from the top of the ingot lost 30.98 per cent more, and those from the middle of the ingot 4.51 per cent more, than those from the bottom of the ingot. At the end of thirty-two weeks those from the top of the ingot lost 10.76 per cent more, and those from the middle of the ingot 1.47 per cent more, than those from the bottom of the ingot. At the end of forty-eight weeks those from the top of the ingot lost .8 per cent more, and those from the middle of the ingot 3.43 per cent less, than those from the bottom of the ingot. At the end of sixty-four weeks those from the top of the ingot lost .22 per cent less, and those from the middle of the ingot 1.72 per cent less, than those from the bottom of the ingot; the great variation in loss of these samples being due probably to a greater amount of impurities of the metal of the ingot in this heat.

When the results obtained from the cold-drawn seamless tubes are investigated, a similar result as in the former cases appears, except that the losses in each series of sixteen weeks is much smaller than in the other cases.

The losses per square inch of area were:

	After 16 weeks (1st 16 weeks)	After 32 weeks (2d 16 weeks)	After 48 weeks (3d 16 weeks)	After 64 weeks (4th 16 weeks)
Tubes from the top of ingot....	.3288	.6166	.4796	.5525
Tubes from the middle of ingot.	.3120	.5278	.4451	.4498
Tubes from the bottom of ingot	.3075	.5645	.4451	.5192

The difference in the losses of these three grades is quite marked; at the end of the first sixteen weeks those from the top of the ingot lost 6.9 per cent more, and those from the middle of the ingot 1.4 per cent more, than those from the bottom of the ingot; at the end of thirty-two weeks those from the top of the ingot lost 9.2 per cent more, and those from the middle of the ingot lost 6.49 per cent less, than those from the bottom of the ingot; at the end of forty-eight weeks those from the

top of the ingot lost 7.7 per cent more than, and those from the middle of the ingot were equal to, those from the bottom of the ingot; at the end of sixty-four weeks those from the top of the ingot lost 6.4 per cent more, while those from the middle of the ingot lost 13.3 per cent less, than those from the bottom of the ingot. **No. 414.**

Sulphur in Coke and its Behavior in the Blast Furnace. F. Wuest and F. Wolff. Iron and Steel Institute, May, 1905. 13,000 w. — The authors describe some experiments conducted to ascertain the behavior of sulphur in the blast furnace consisting chiefly in the determination of the combustible sulphur and in the reaction of that element when brought in contact at a high temperature with hydrogen, steam, nitrogen, carbon monoxide and carbon dioxide. From their results they draw the following conclusions:

" Contrary to the generally held opinion, the sulphur in the coke does not reach the level of the tuyères of the blast furnace without undergoing alteration, but a great portion of it is previously volatilized by the ascending gases, and is then largely absorbed from the gases by the descending charge, and in this condition arrives in front of the tuyères.

" Up to 800 degrees the sulphur is principally absorbed by the oxides of iron from the sulphur-laden gases, while from 800 degrees upwards the position is reversed, and the lime becomes the chief absorbent of the sulphur." **No. 415.**

Britain's Earliest Iron Furnaces and Molding Floors. Thomas May. " The Iron and Coal Trades Review," August 11, 1905. 10,000 w., illustrated. — The author describes with numerous illustrations the Roman methods of manufacturing iron as evidenced by the remains of smelting, molding and other furnaces discovered during recent excavations which he conducted within the Roman fortifications at Wilderspool, near Warrington. **No. 416. A.**

The Testing of Cast Iron. Richard Moldenke. " Journal of the Franklin Institute," June, 1905. 5,000 w. — The author reviews the progress made in the testing of cast iron, with special reference to American practice. **No. 417. C.**

The Bertrand-Thiel Process. E. von Maltitz. "The Iron Age," August 10, 1905. 9,000 w. — The author describes the Bertrand-Thiel process as conducted at Kladno and elsewhere and shows how it can be introduced with good results in almost any open-hearth steel plant. **No. 418. A.**

METALLURGICAL NOTES AND COMMENTS

Sir Lowthian Bell * Sir Lowthian Bell, who died on December 20, 1904, was born in Newcastle on February 15, 1816, and educated, first at Bruce's Academy in Newcastle, and afterwards in Germany, in Denmark, at Edinburgh University and at the Sorbonne, Paris.

On the completion of his studies, Lowthian Bell joined his father at the Walker Iron Works. Mr. John Vaughan, who was with the firm, left about the year 1840, and in conjunction with Mr. Bolckow began their great iron manufacturing enterprise at Middlesbrough. Mr. Bell then became manager at Walker, and blast furnaces were erected under his direction. He became greatly interested in the ironstone district of Cleveland, and as early as 1843 made experiments with the ironstone. He met with discouragements at first, but was rewarded with success later, and to Messrs. Bell Brothers largely belongs the credit of developing the ironstone field of Cleveland. Mr. Bell's father died in 1845, and the son became managing partner. In 1852, two years after the discovery of the Cleveland ironstone, the firm acquired ironstone royalties first at Normanby and then at Skelton in Cleveland, and started the Clarence Iron Works, opposite Middlesbrough. The three blast furnaces here erected in 1853 were at that time the largest in the kingdom, each being 47½ feet high, with a capacity of 6,012 cubic feet. Later furnaces were successively increased up to a height of 80 feet in 1873, with 17 feet to 25 feet in diameter at the bosh, 8 feet at the hearth, and about 25,500 cubic feet capacity.

Sir Lowthian earned great repute as an author. He was a prolific writer on both technical and commercial questions relating to the iron and steel industries. His first important book was published in 1872, and was entitled "Chemical Phenomena of Iron Smelting: An Experimental and Practical Ex-

* Extracted from "The Journal of the Iron and Steel Institute," No. XI, 1904.

amination of the Circumstances which Determine the Capacity of the Blast Furnace, the Temperature of the Air, and the Proper Condition of the Materials to be Operated Upon." This book, which contained nearly 500 pages, with many diagrams, was the direct outcome of a controversy with the late Mr. Charles Cochrane, and gave details of nearly 900 experiments carried out over a series of years with a view to finding out the laws which regulate the process of iron smelting, and the nature of the reactions which take place among the substances dealt with in the manufacture of pig iron. The behavior of furnaces under varying conditions was detailed. The book was a monument of patient research which all practical men could appreciate. His other large work, covering 750 pages, was entitled, "The Principles of the Manufacture of Iron and Steel." It was issued in 1884, and in it the author compared the resources existing in different localities in Europe and America as iron-making centers. His further investigations into the manufacture of pig iron were detailed, as well as those relating to the manufacture of finished iron and steel.

In 1886, at the instance of the British Iron Trade Association, of which he was then president, he prepared and published a book entitled, "The Iron Trade of the United Kingdom Compared with Other Chief Iron-Making Nations." Besides these books and numerous papers contributed to scientific societies, Sir Lowthian wrote more than one pamphlet relating to the history and development of the industries of Cleveland.

In 1876, Sir Lowthian was appointed a Royal Commissioner to the Centennial Exhibition at Philadelphia, and wrote the official report relating to the iron and steel industries. This was issued in the form of a bulky Blue-Book.

As a director of the North-Eastern Railway Company, Sir Lowthian prepared an important volume of statistics for the use of his colleagues, and conducted exhaustive investigations into the life of a steel rail.

The majority of his papers were read before the Iron and Steel Institute.

To him came in due course honors of all kinds. When the Bessemer Gold Medal was instituted in 1874, Sir Lowthian was the first recipient. In 1895, he received at the hands of the King, then Prince of Wales, the Albert Medal of the Society of

Arts, in recognition of the services he had rendered to arts, manufactures and commerce by his metallurgical researches. From the French government he received the cross of the Legion of Honor. From the Institution of Civil Engineers he received the George Stephenson Medal in 1900, and, in 1891, the Howard Quinquennial Prize which is awarded periodically to the author of a treatise on iron.

For his scientific work Sir Lowthian was honored by many of the learned societies of Europe and America. He was elected a Fellow of the Royal Society in 1875. He was an Honorary D.C.L. of Durham University; an LL.D. of the Universities of Edinburgh and Dublin; and a D.Sc. of Leeds University. He was one of the most active promoters of the Durham College of Science by speech as well as by purse; his last contribution was made only a short time ago, and was £3,000, for the purpose of building a tower. He had held the presidency of the North of England Institution of Mining and Mechanical Engineers, and was the first president of the Newcastle Chemical Society.

In the Iron and Steel Institute he took special interest. One of its original founders, in 1869, he filled the office of president from 1873 to 1875.

Cast-Iron Wheels. — The discussion which has been going on recently over the use of cast-iron wheels under high-capacity cars differs somewhat from previous discussions, which have taken place periodically during the last twenty years, in that the purely mechanical problem of producing a wheel of chilled cast iron which is safe and which will give good service has been lost sight of. The discussion has hinged on the commercial problem of whether or not a cast-iron wheel can be made for a certain price and at the same time be safe and give long service. The mechanical problems involved in the design and manufacture of cast-iron wheels for freight cars are more difficult than they have ever been before, because of the greater loads and speeds, but, at the same time, they are not impossible of solution.

Briefly stated, the wheel situation is this: Cast-iron wheels under high-capacity cars are not giving altogether satisfactory service, and with the keen competition and the severe tests required, coupled with the unwillingness on the part of the railroads to pay more for a higher quality wheel, the problem has

resolved itself into one of how good a wheel can be made for a certain price. And this commercial aspect, as before said, has caused both wheel makers and railroads to lose sight of the more important mechanical problems. Mr. Griffin, speaking for the wheel makers, admits that their chief aim is to make wheels as cheaply as they can be made and stand the tests imposed by the railroads, without regard to durability; and the railroads, in trying to save money on renewals, endeavor to turn back on the makers as large a share as they can of the wheels which are condemned. Both parties are trying to save pennies by working at cross purposes, when they might be saving dollars by working together.

The cast-iron wheel has come in for much more than its fair share of condemnation since the introduction of the high-capacity car. Because it has failed under such cars more frequently than under cars of lighter capacity, its enemies have been quick to claim that it was unfit for such service, when, as a matter of fact, almost any type of wheel would have failed under similar conditions. The most frequent cause of failure of wheels is the heating action of the brake shoes combined with the rubbing of the flange against the rail. As far as vertical strength is concerned, the cast-iron wheel apparently has an ample reserve; but under high-capacity cars the braking action and the flange wear are both much more severe. Normally, there is no flange wear on straight track, unless the truck fails to return to its normal position after leaving a curve. If a car has weak bolsters or badly designed center plates and side bearings a truck may be held in a slued position, and the wheel flanges grind on the inside of the rail mile after mile. Any wheel would show flange wear under these conditions, and it is obviously unfair to criticise the cast-iron wheel because it fails under such conditions. The fault is not with the wheel.

The heating action of the brake shoes under heavy cars is much more severe than under light cars, for two reasons: First, because there is more braking pressure with practically the same area for radiation of the heat; and, second, because, as a rule, the high-capacity cars are braked more continuously — a larger part of the time — than the lighter cars. In making up trains the heaviest and strongest cars are usually put next to the engine, and the light cars in the rear of the train. The trainmen

then couple up the air brakes on the first ten or fifteen cars and depend on the brakes of those cars to control the entire train. This practice has been very general up to the time when the statutory requirement of 50 per cent came into operation. On mountain roads, where retaining valves are used, the front cars in a train may have the brakes applied continuously for as long as an hour, while the rear cars have only a few hand brakes set up. This practice undoubtedly has much to do with the larger percentage of wheel failures under high-capacity cars than under cars of lighter capacity. We are not criticising the practice, because experience has shown that in many situations probably this is the best way to control a train; we simply are pointing out that it is not fairly the fault of the wheel when it fails under such service.

We do not here discuss the relative merits of the different designs of single and double plate wheels, with and without brackets, which have been suggested as improvements over existing designs. Experience only can determine whether or not minor changes in the shape and location of the brackets and plates will prevent troubles from cracks in the body of the wheel due to uneven expansion, or whether they will assist in radiating the heat from the tread to such an extent as to eliminate part of the trouble from transverse and longitudinal cracks. The most radical suggestion which has been made is to thicken the flange and to enlist the coöperation of the maintenance of way departments to increase the clearance at frogs and guard rails so that a thicker flange may be used. With a thicker flange more gray iron can be used to reinforce the weakest point of the wheel without sacrificing any of the chill. From experience on the Southern Railway it would seem that this can be done with no difficulty.

Viewing the whole matter impartially there would seem to be no reason to doubt that some of the many expedients proposed to improve the quality and increase the strength of cast-iron wheels will eventually prove satisfactory; will remove all ground for fear that the cast-iron wheel is unsafe and cannot be made safe to run under the conditions of modern service. The best care on the part of the founder and the use of high-grade charcoal iron would eliminate many of the troubles now experienced; and as regards this feature of the matter it is only a

question of whether the railroads prefer to pay a moderate price for the better material and for the better foundry practice adopted, or to pay much more for steel wheels, which apparently have an excess of strength, but which have not yet shown that they have sufficiently longer life to pay for the difference in first cost. It is a significant fact that in their petition to the Master Car Builders' Association, asking to have the guaranty reduced, the wheel makers made no claims about being able to produce a wheel to meet the present guaranty if the railroads were willing to pay for it. This can hardly be taken as an admission that they cannot produce such a wheel, but it would have made their position stronger had they offered a specification and a guaranty for higher-priced wheels, and had shown that they were prepared to furnish such wheels if the railroads wanted them. Their attitude is thus a defensive one, and they have not strengthened their position by taking it. Meanwhile, the steel-wheel makers are taking every advantage of the situation to secure favor, and by means which necessarily tend to create distrust of the cast-iron wheel. The question is not yet by any means settled, but nothing has occurred thus far to justify the notion that the chilled-wheel makers must go out of business. They know how to make better wheels, and they ought to know how to induce the railroads to use better wheels. "Railroad Gazette," July 14, 1905.

The Héroult Process in Sheffield. — The acquisition from the Société Electro-métallurgique Française, of Troyes, of the British patent rights in the Héroult process for the electrical production of steel by the Sheffield Steelmakers (Lim.), of Sheffield, will, if the expectations of the owners of the patents are fulfilled, mark the beginning of a new era in steel manufacture in Sheffield.

Mr. P. R. Kuehnrich, the head of the Sheffield Steelmakers (Lim.), has been interviewed by us, and has made the following statements, which, it will be understood, are given entirely on his own responsibility:

On inquiring what advantages were claimed for steel smelted in the Héroult furnaces over that produced by other methods, our representative was informed that the quality of steel obtained by the electric process is not merely equal to the highest grades of crucible carbon tool-steel, but is even better,

especially as regards the uniformity of the material obtained. In, say, a 4-ton charge of steel made in the Héroult furnace, the whole of the ingots can be depended upon to agree in one uniform analysis, there being a complete absence of any tendency to segregation.

Asked what is likely to be the immediate consequence of the introduction of the Héroult process into Sheffield, Mr. Kuehnrich expressed himself as follows: "As a matter of fact Sheffield can, if it wants to do so, immediately emancipate herself from Sweden, since in the Héroult furnace we can produce from English scrap or ore iron purer than any coming from Sweden. The analysis of some ingots of such iron which our friends have made in the Héroult furnace reads as follows:

Sulphur	0.020
Phosphorus	0.005
Manganese	0.000
Carbon	0.010
Silicon	0.005

This may be termed chemically pure iron."

Our representative inquired whether Mr. Kuehnrich considered this "Héroult" iron as good as the fine Swedish brands which have been treasured in Sheffield for so many generations, and have always been thought irreplaceable, and received the following reply: "There are strong opinions — and I confess I was myself formerly a holder of the theory — that there is something indefinable, but of unique character, in the choice brands of Swedish and Styrian irons unattainable in any other material, giving steel made therefrom that fine cutting and wearing quality so much appreciated. It is true, Bessemer and Siemens-Martin steels have been made with analyses practically matching those of the steel made from Swedish and Styrian irons, but the results did not bear out the anticipations of the analysis. The Héroult process will not only affect the Swedish iron exports to Sheffield, but will, I think, deal a blow at the Swedish Bessemer and Siemens steelworks there as well. We claim to be able to produce by the Héroult plant a special quality of steel which, though as cheap in its production, is far superior to the Swedish Siemens and Bessemer steel."

"Do you expect that the Sheffield cutlery manufacturers will take up your material?" "The introduction of our elec-

tric steel into Sheffield will tend to raise the standard of quality of its cutlery, which during the last fifteen to twenty years has deteriorated considerably. Generally speaking, Sheffield knives do not now cut so well as formerly, since competition has forced makers to employ cheaper qualities of steel than were used in former days. ' Héroult ' electric steel is bound, I think, to help to regain for Sheffield that prestige of ages which has undoubtedly somewhat suffered."

" We claim that we can make high-class steel of a greater uniformity than is possible by any other process. Therefore our electric steel is the steel of the future for tools in general, rifle barrels, swords, bayonets, heavy ordnance, armor-plates, w res of high tensile and breaking strains, and almost endless other purposes. But the matter does not end there. It will set fresh standards for purposes where it has hitherto been thought that a lower-grade steel was good enough. For instance, for railway material, such as locomotive tires and axles, where greater purity and uniformity of steel insures greater safety, and for structural purposes, where lighter material will give the same strength as heavier sections of current type of steel material. I foresee that railway companies, government departments and corporations will alter the whole of their specifications, which already have well-nigh given nightmares to the hapless steel producers by ordinary methods." " The Iron Monger," July 22, 1905.

Some Notes on the Galvanizing Industry. — As compared with the production of tin plate, galvanizing is comparatively a new industry, having only been worked in Europe since the early part of the last century and introduced into the United States from England. The industry at the present time has assumed large proportions, the value of the shipments of galvanized roofing sheets amounting to over £1,000,000 sterling per annum, but the profits are comparatively small compared with those made thirty years ago, when many large fortunes were made.

The first method for coating iron with zinc was electrolytic, that is, a solution of zinc such as zinc sulphate or chloride was employed through which an electric current was passed, the work to be zincked forming one pole and a sheet of zinc the other.

The wet or electrolytic process was soon abandoned in favor of the hot or molten process, as there were no efficient low-tension dynamos which were essential for the economical working of such a process, and the coating applied was found to be unreliable. The hot or molten process consists of dipping the article into a molten bath of zinc (at a temperature of about 800° F.) covered with a suitable flux, such as sal ammoniac. From time to time various improvements, relating to the mechanical details, have been introduced into the working of the hot process, having for their object the reduction of the amount of zinc consumed for a given area of iron, but, unfortunately, such a reduction results in a corresponding decrease in the durability of the galvanized article. Sheets are passed through squeezing rolls as they leave the bath; wire through asbestos rubbers or sand; nails and similar articles are placed, when the zinc is still molten, in centrifugal machines to remove as much zinc as possible. Another improvement of some moment has been the introduction of close annealing to reduce the amount of oxide formed, and the subsequent removal in acid. Sand-blasting, that is, projecting sand at a few pounds pressure on the article to be freed from scale, has been substituted for the wet acid process for some classes of work. Serious attempts have been made on several occasions to introduce lead galvanizing instead of zinc galvanizing, so as to take advantage of the cheapness of the former metal, but lead-coated articles are not found to be so durable as zinc coated, on account of the lead being electro-negative to the iron instead of positive as in the case of zinc. If the lead coating is penetrated the iron is rapidly corroded; in the event of the zinc coating being perforated the zinc is slowly attacked and the iron preserved. The electrical relation of zinc and lead to iron is readily demonstrated by immersing in water pieces of zinc-galvanized iron and lead-galvanized iron, the surfaces of both having been previously penetrated. In a comparatively short time, in the first case, zinc oxide will be noticed at the bottom of the vessel, and in the other the water will rapidly redden and large patches of red oxide of iron appear.

During the last ten years a number of electro-galvanizing plants have been erected in almost every large shipbuilding yard in England and on the Continent, as it has been found that zinc can be very cheaply deposited with the modern efficient dynamo

of large amperage and small voltage. The process is employed by the Admiralty for flashing or coating boiler tubes with a very thin coating of zinc for the purpose of preventing corrosion and pitting during the time of erection and assembly, and to enable flaws to be detected in the tubes at an early stage, as a thin coating of zinc applied to the tubes is found to show up any inherent defect very clearly. The process that has been adopted largely in this country and by the German government, Messrs. Krupps, Messrs. Cockerill and others on the Continent, is the regenerative process, which is automatic in action. The zinc, as deposited on the iron, is replaced by circulating the solution over zinc dust (a product of the zinc distillation furnace) mixed with fine coke so as to form a filter bed. Electro-galvanized iron is free from the spangled or crystalline effect obtained by the hot process, which is one of the reasons it has not been found suitable for galvanizing sheets for roofing purposes, as certain foreign markets attach great importance to this crystalline effect, although many of our most enlightened engineers now specify that galvanized iron shall not be spangled, as it is obtained at the expense of the durability of the iron, tin being added in many cases to increase the size and brilliancy of the spangles.

The latest development in the galvanizing industry is a dry galvanizing process, which is an entirely new departure, as is does not embody any of the essential features of the hot and electric process. The new process, which is known as " Sherardizing," consists in placing the iron article to be galvanized, without any preparatory treatment beyond the removal of the matte scale, in a closed receptacle filled with zinc dust, which is heated to a temperature several hundred degrees below the melting point of zinc, for such a period as will give the desired thickness of zinc. The process for such articles as bolts, nuts, nails, small castings, etc., is found to be more economical than hot galvanizing or electro-galvanizing, and the coating very durable, as a true alloying or amalgamation of the zinc takes place with the surface of the iron. The surfaces obtained by hot and cold galvanizing and Sherardizing are different in each case, but they can readily be distinguished by those conversant with the three processes. In the case of hot galvanizing, the surface is spangled, or if not spangled, has the appearance of cast metal. In the case of cold galvanizing, the surface is free from spangles,

and has a matte or frosted surface, uniform if the work has been well executed. Sherardizing is, again, distinctive from the two former processes; the general appearance resembles more that of cold galvanizing than hot galvanizing, but is more lustrous and metallic, and is uniformly distributed over the whole surface, which is not the case with the hot and cold galvanizing processes. The hot and dry galvanizing processes are both consumers of heat, and no doubt gas firing with Mond or a similar gas will effect considerable economy over the present methods of coke firing; and the development of cheap electrical power on a large scale should give a fresh impetus to the electro-galvanizing, which is entirely dependent on cheap electricity for its commercial development, if it is to embrace any of the fields which are at present entirely monopolized by the hot or molten process.

Great Britain was the first to establish the galvanizing industry, which is now one of vast importance, and it is to be hoped she will continue to take the lead by embracing those opportunities which occur from time to time of combining recent improvements with cheap power and fuel, which will enable her to retain many of her colonial and foreign markets, which are now being contested so keenly by the Belgians, Germans and Americans. Sherard Cowper-Coles in "Iron and Steel Trades Journal," July 8, 1905.

Nickel Steel Winding Rope Wire. — Mr. J. Devis has recently carried out some experiments in order to test the possibility of using nickel steel wires of low nickel content for hoisting purposes. He finds that wires with a high content of nickel are not suitable for the manufacture of winding rope of high carrying capacity, on account of their low strength and softness. Inasmuch as the capability of iron for taking up carbon decreases considerably with increasing amounts of nickel present, and as the high strength of steel wires is principally due to their higher content of carbon, wires of a high carrying capacity are only manufactured with a low content of nickel.

In the experiments special pains were taken to get true comparative results between the steel wires with or without nickel.

The first experiments were carried out with a nickel steel wire, containing 5.74 per cent nickel and having a strength of 145,000 to 146,500 pounds per square inch. The results ob-

tained were as follows: Thickness of wire, average, 1.985 mm.; tensile strength, 170,000 to 184,000 pounds per square inch; number of torsions, 45.2; number of bendings, 16.2. Experiments were also carried out in which the wires were subjected to repeated shocks. A second series of experiments with the same material was carried out to test the difference exerted upon its mechanical properties after it had been exposed for eight weeks to the action of steam above the exhaust of an engine and had become covered with rust. The experiments showed that the strength was not influenced to any large extent, but that the bending capacity was reduced by 41.4 per cent, and the torsional capacity had suffered the still greater reduction of 49.7 per cent. The presence of nickel, amounting to 5.74 per cent, therefore, exercised no influence to prevent the rusting.

Comparative experiments, carried out with winding rope wires of the same steel material but without the addition of nickel, which had nearly the same strength as the wire containing nickel, namely, 170,000 to 184,000 pounds per square inch, showed that these wires possessed the same bending capacity as the nickel wires tested previously, but had a smaller torsional capacity. Experiments were also conducted with these wires after they had been rusted in the same manner as above. They showed that the strength decreased somewhat, while the bending capacity decreased 33.8 per cent, and the torsional capacity 24.7 per cent. Other experiments were carried out with nickel steel wires containing 1.89 per cent nickel, which had a strength of 256,000 to 284,000 pounds per square inch, and with ordinary steel wires of about the same strength. The experiments showed that a favorable influence of the nickel present on the mechanical properties of the wire could not be ascertained.

In order to find out whether a larger amount of nickel in the wire exerts a favorable influence on its properties, nickel steel wires were tested, containing 6.28 per cent nickel, which had a carrying capacity of 256,000 to 284,000 pounds, and compared with the results obtained from ordinary steel wires of the same material, as to their resistance to the influence of rust and their mechanical properties, as well as to their behavior when subjected to bending, torsion and shocks. It was found that in this case also a rust-preventing property of the 6.28 per cent nickel in the wire could not be established.

In reviewing the experiments, Mr. Devis thinks that at the present time nickel steel cannot come into consideration as a material for winding ropes. "Iron and Coal Trades Review," August 4, 1905.

British Foundrymen's Association

The second annual convention of the British Foundrymen's Association was held in Glasgow on August 7, 8 and 9. The membership, which at the last meeting was 83, now stands at 121. It was reported that the council had made arrangements for the publication of a journal in which would appear the papers read as well as the other transactions of the society. Messrs. Robert Buchanan, Herbert Pilkington and F. W. Finch were re-elected respectively president, vice-president and secretary.

Mr. Buchanan delivered his presidential address and the following papers were read and discussed:

"Technical Education and the Foundry," by Professor Sexton.

"Cast Iron," by Herbert Pilkington.

"Molding Sands and Fire Clays," by Percy Longmuir.

"The Microscope and Pig Iron," by A. Campion.

"Profitable Foundring," by John G. Stewart.

Moisture and Furnace Results. — At the Liége Metallurgical Congress, M. Divary, of Schneider & Co., Creusot, France, gave some interesting information on the occasion of the discussion of Mr. Gayley's dry-air process. The observation was made for many years at Creusot that consumption of coke increased and the output of the furnace decreased in summer as compared with winter, and in 1901 records were kept, which in August, 1902, led to a first study . The result of this study was that an economy of 50 to 60 kilograms of coke per ton of iron seemed in sight if the furnace was blown with air saturated at 0° C. in place of hot and humid air during the summer months.

These researches were continued, and since the difference in consumption of coke observed during one year seemed larger than those justified by calculation it was determined to carry out the system of drying the air by freezing. This was submitted in September, 1903, to several designers of ice machines.

After their figures had been received other questions claimed the attention of Schneider & Co., so that the program was not immediately carried out, but instructions were given to the blast-furnace department to observe daily the humidity in the air and the corresponding fuel consumption under conditions guaranteeing accuracy. Three times per day the moisture was observed in the blowing room.

During the year 1904 the charge remained practically the same, the two furnaces, Nos. 2 and 4, running on basic-Bessemer pig. The results are shown in the following table, the first column showing the average amount of moisture per cubic meter of air blown in during the month, the second column the increase in the consumption of coke as compared with that of the driest month, and the third column showing the average production per furnace for twenty-four hours:

Month	Moisture in Blast Gr.	Increase in Coke Consumption Kg.	Average Furnace Product Tons
January	6.3	0	90.5
February	6.6	10	88.7
March	7.6	13	87.2
April	7.8	47	81.2
May	10.0	56	78.3
June	11.7	103	75.7
July	13.0	133	70.0
August	12.0	90	76.6
September	9.3	55	90.0
October	8.0	28	86.0
November	7.6	25	86.5
December	7.0	35	88.5

At Creusot the speed of the engines is not lowered in winter, and the blast is always heated to the same temperature, summer and winter, being an average of 752° C.

The figures agree very closely with those of Mr. Gayley and hold out undoubtedly the results to be obtained from drying blast-furnace blast. "Iron Age," August 17, 1905.

Production of Manganese Ores in 1904. — California, Utah and Virginia were the only states that produced manganese ore in 1904. The total production for the year amounted to 3,146 gross tons, valued at $29,466, or $9.37 a ton. This is 321 gross tons, or 11 per cent, more than the quantity reported in 1903, which was 2,825 gross tons. Of the total production in 1904, 3,054 gross tons, or 97 per cent, came from Virginia, 60 gross

tons, or 2 per cent, came from California and 32 gross tons, or 1 per cent, came from Utah.

In addition to the true manganese ores considerable quantities of manganiferous iron ore are produced in Arkansas, Colorado and in the Lake Superior region. This amounted in 1904 to 383,246 gross tons, which had a reported value at the mines of $691,477. In Arkansas 600 tons of ore of this class, carrying 28 per cent of manganese and 10 to 14 per cent of iron, were mined and used in the manufacture of pig iron. The Colorado ores are utilized primarily as flux by the precious metal smelters, the remainder being employed in the manufacture of spiegeleisen. In the Lake Superior region quantities of iron ore are mined which analyze from a fraction of 1 per cent up to 20 per cent of manganese.

In mining silver ores in Colorado a considerable quantity of ore is obtained which contains insufficient percentages of the precious metal to make it valuable on that account, but which is used as a flux by the smelters. This ore is considered an iron ore and is included in the report on that mineral. In 1904 the production of manganiferous silver iron ores in the United States amounted to 105,278 gross tons, valued at $348,132. This is considerably less than the production of 1903, which amounted to 179,205 tons, worth $649,727.

A by-product in the manufacture of zinc from ores mined in northern New Jersey, containing iron and manganese, is utilized in the production of spiegeleisen. In 1904, 68,189 gross tons of this class of ore were obtained.

The total quantity of manganese ore, manganiferous iron ore, argentiferous manganiferous ore and zinc residuum produced in the United States in the calendar year 1904 amounted to 559,859 gross tons.

The above-mentioned facts are taken from a recent report made by Mr. John Birkinbine for the United States Geological Survey. "Bulletin," American Iron and Steel Association, August 15, 1905.

The Wonderful Lake Superior Region. — We compile below, from the report of John Birkinbine to the United States Geological Survey on the production of iron ore in 1904, a table showing the relative prominence of the Lake Superior region as

an iron ore producer in the last three years as compared with the remainder of the country. The loss in production in 1904 will doubtless be fully balanced by an increased production in 1905.

States — Gross Tons	1902	1903	1904
Minnesota	15,137,650	15,371,396	12,728,835
Michigan	11,135,215	10,600,330	7,089,887
Wisconsin	783,996	675,053	483,745
Total	27,056,861	26,646,779	20,302,197
All other states	8,497,274	8,372,529	7,342,133
Grand total	35,554,135	35,019,308	27,644,330

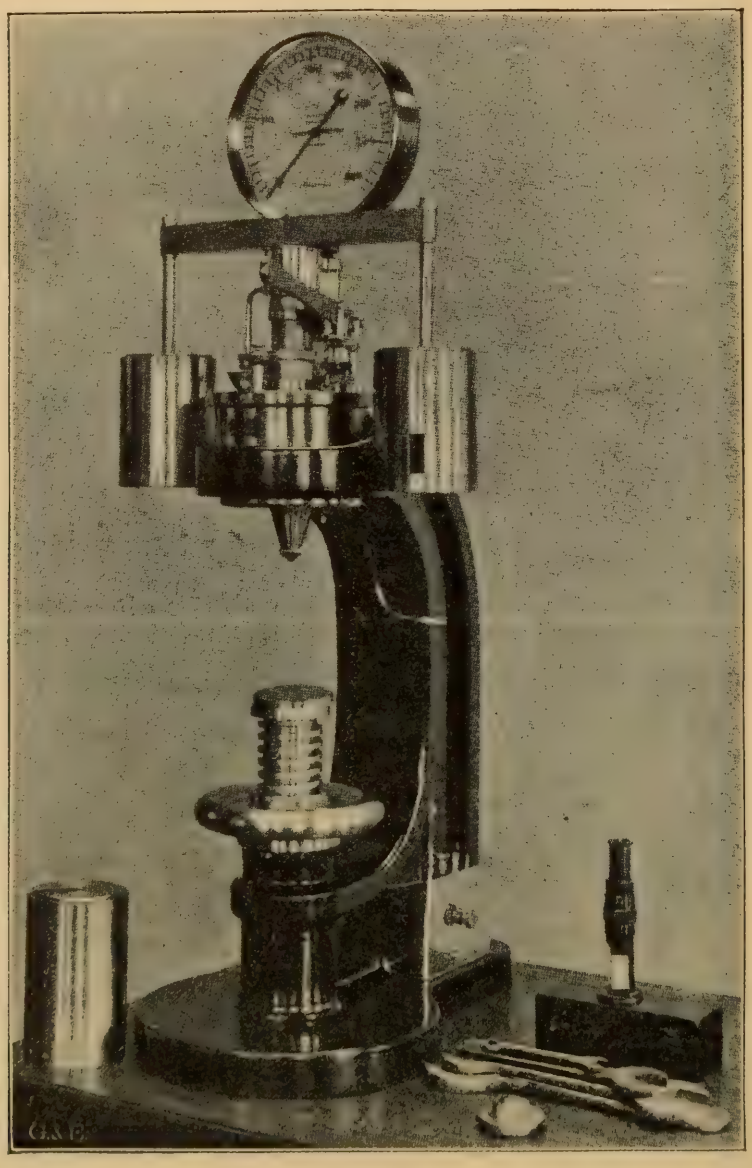
The total value of Lake Superior iron ore at the mines in 1902, as given by Mr. Birkinbine, was $52,485,951; in 1903, $53,858,635; and in 1904, $32,934,873. Of this value much the larger part was, of course, paid to labor. The shrinkage in production and value in the reactionary year 1904, as compared with the two preceding years, shows how seriously the iron ore interests of the Lake Superior region are affected by a depression in the American iron trade.

The above figures make plain a truth that needs to be generally recognized, although it is self-evident. A brisk demand for the raw materials of our iron and steel industries, iron ore, coke, coal, limestone, etc., cannot be maintained if the demand for the finished products declines from any cause whatever. "Bulletin," American Iron and Steel Association, August 15, 1905.

The Brinell Ball Test

The accompanying illustration shows a machine constructed in Sweden for determining the hardness of metals by the Brinell method, which consists in forcing a steel ball into the metal under a known pressure and in measuring the spherical depression produced thereby. By dividing this depression by the corresponding load the "factor of hardness" is obtained. From this factor of hardness the tenacity of the metal may also be calculated with sufficient accuracy for most practical purposes, thus doing away with the costly preparation of test pieces for the ordinary tensile test. The ball test may, moreover, be applied to finished implements,

such as rails, projectiles, armor plates, machinery parts, etc. Its usefulness in ascertaining the effect of hardening and tempering will also be obvious. The hydraulic machine illustrated here for conducting the ball test attracted much atten-



tion at the Liége Exposition. It is said to be very practical, of easy manipulation and absolutely accurate. The machine is constructed by the Alpha Company (Aktiebolaget Alpha), of Stockholm, Sweden.

REVIEW OF THE IRON AND STEEL MARKET

September has been a remarkable month in the American iron trade. There has been an improvement in every individual line. The demand for steel for the different finishing lines has become so great that scarcely any crude steel can be obtained in the open market. This demand has in turn been reflected in pig iron, but not to so great an extent, as demand for forge and foundry grades has not been abnormally heavy.

During October substantially the entire steel producing capacity of the country will be operated to the full limit, even including the old Columbus Bessemer steel works, which are run only in times of extreme demand. The pressure is not uniformly distributed among the various finishing lines. In rails, shapes and plates the demand is far ahead of capacity. In merchant steel bars it is fully up to capacity. In wire products, sheets, merchant pipe and tin plates it is scarcely up to total finishing capacity, the deficiency being somewhat in the order in which these products have been named. It is always the case with the trade that the total finishing capacity, in all lines, is beyond the steel producing capacity. It would be simply impossible to supply steel for operating all finishing mills to full capacity, and the trade is already on the verge of an absolute famine in crude steel.

Pig Iron. — It can be stated as a general proposition that all the blast furnaces of the country are in operation except such as are off for absolutely necessary repairs and such as it is not economical to operate even with the present moderately high market prices. Production is at a slightly higher rate than at any time since July 1, but is under the rate maintained for a short time in the latter part of the first half. At that time furnaces were in better than normal condition, owing to much relining and repair work having been done in the lull last year. Sales of all grades have been fairly heavy. The market has advanced an average of about 50 cents during September. Furnaces in general are well sold up for several months ahead.

A number of steel works producing pig iron themselves have been good buyers of Bessemer and basic. The United States Steel Corporation has resumed making monthly purchases of pig iron, taking 35,000 tons of Bessemer for September delivery and a larger quantity for October. We now quote prices as follows: F.o.b. valley furnace: Bessemer and basic, $15.00; No. 2 foundry, $14.75 to $15.00; gray forge, $13.90 to $14.00; low phosphorus, $20.75. Delivered Pittsburg: Bessemer and basic, $15.85; No. 2 foundry, $15.60 to $15.85; gray forge, $14.75 to $14.85. F.o.b. Birmingham: No. 2 foundry, $12.00; gray forge, $10.75, for nearby delivery, most southern furnaces asking 50 cents advance for next year's delivery. Delivered Philadelphia: No. 2 X foundry, $16.50 to $16.75; standard gray forge, $14.75 to $15.25. Delivered Chicago: northern No. 2 foundry, $16.25 to $16.50; malleable Bessemer, $17.00 to $17.25. Freight: Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65; to Philadelphia by water, $3.50; by all-rail, $4.00.

Steel. — After having been almost the only seller of crude steel during August, the Carnegie Steel Company about the first of September withdrew entirely from the market, and no seller of consequence appeared to take its place. While consumers in general were well covered, inquiries aggregating more than 30,000 tons have been turned down. The only sale of any magnitude was one of 10,000 tons of Bessemer billets from a producer to another producer, making only open-hearth steel. Such transactions are not market indications, as steel producers make special efforts to accommodate each other. We quote Bessemer billets largely nominal at $25.00 and open-hearth at $26.00, these prices representing an advance of $1.00 a ton during the month. There are no open quotations on sheet bars, but the settlement price on long-term contracts, subject to monthly price adjustment, is $26.00 for October deliveries, a large tonnage being controlled by such contracts. Forging billets in small lots are bringing as high as $28.00. Rods are quoted at $31.00 to $32.00. All prices are f.o.b. Pittsburg.

Rails. — Since the last week in August rail mills have been booking tonnage for 1906, at $28.00, f.o.b. mill, which has been the price since the advance made in the spring of 1901. Fully 1,500,000 tons have been booked, and a considerable tonnage,

perhaps 250,000 tons, will have to go over from this year, so that more than half the record production for any year has already been sold, with every indication that 1906 will break records. Production this year will be much larger than early estimates, as in the second half all possible capacity is engaged on rails, while in the first half a considerable tonnage of billets and sheet bars was being produced by the convertible mills.

Shapes.— On August 31 all structural shapes were advanced $2.00 a ton, making official prices the highest since 1899, as follows: Beams and channels, 15-inch and under, angles 2 x 3 to 6 x 6 inclusive, and zees, 1.70 cents per pound; tees, 3-inch and larger, 1.75 cents; beams and channels over 15-inch, 1.80 cents, all f.o.b. Pittsburg, carload and larger lots. The large structural mills are filled with actual specifications which it will take from five to six months to roll, and deliveries for this year can be obtained only from stocks which are much depleted, and from a few small mills which do not sell so far ahead. A large tonnage is being booked for 1906 delivery, chiefly for definite undertakings, a few running contracts being made with fabricators and dealers.

Plates. — During September orders have been placed by various railroads for about 50,000 steel and steel underframed cars, engaging the capacity of car builders until about July 1 next. Plates for these cars have been placed as the car orders came in, and there has also been good buying for shipbuilding and other purposes for next year. The plate mills are, on an average, sold up for four or five months ahead, and early deliveries are hard to get. A general advance in plates is likely to be made during October. The mills have already advanced plates 14 inches wide and narrower by $2.00 a ton, placing them on the same basis as wider plates. We now quote the regular mill price at 1.60 cents for tank quality, quarter-inch and heavier, 6¼ to 100 inches wide inclusive, with the usual advances for other sizes and grades.

Merchant Bars. — Contracting for future delivery continues very heavy, and specifications are in hand for several months ahead. Hoops have been advanced $2.00 a ton to 1.75 cents, base, with full hoop extras. Merchant steel bars continue at 1.50 cents. An advance in both hoops and steel bars will probably be made during October. Common iron bars

have been steadily advancing, and the market is now 1.70 cents, f.o.b. Youngstown, 1.75 cents, Pittsburg, and 1.65 cents, Chicago.

Sheets. — A very large tonnage of sheets has been booked, and this, with the steadily advancing prices of steel, should have resulted in a fair advance in sheets before this, but so far no more can be reported than that extreme concessions have been withdrawn in the past fortnight. So far as ordinary carload business is concerned, the market is lower than it was a month or two months ago. We quote on ordinary carloads for mill shipment, with desirable specifications, 2.25 to 2.30 cents on black and 3.30 to 3.35 cents on galvanized, No. 28 gauge. On very large lots these prices could be shaded $1.00 a ton, but not more. Some of the independent mills are filled for the present, and will not do these prices. The leading interest has booked a large tonnage and is now operating more than 85 per cent of its sheet capacity. Corrugated roofing is $1.65 to $1.75 per square for painted and $2.85 to $2.95 for galvanized, No. 28 gauge. The special rebate of 15 cents a box on tin plate, in addition to the regular rebate of 5 cents a box from the official price of $3.55 for 100-pound cokes was made to expire October 5, but as the market is but slightly improved no great change in net prices is to be expected, although the form of quotation may be changed.

Wire Products. — New official prices have been put out, based on $1.75 for nails in carload and larger lots to jobbers. These prices represent a reduction of $1.00 a ton in official quotations, but former quotations were being regularly shaded $2.00 a ton or more, so that the market is really higher. Tonnage has been good and wire mills are operating to almost full capacity. Production was restricted during July and August and stocks are not large.

Scrap. — Prices have advanced further, and dealers are in expectation of a further advance when wintry weather sets in, so that they are accumulating considerable scrap, and it is believed paying higher prices in some instances than could be realized on prompt sales to consumers. We quote heavy melting stock at about $16.00, delivered Pittsburg. Cast borings are firm at our former quotation of $9.50 to $10.00. Sheet scrap is bringing $14.25.

STATISTICS

Half Yearly Production of Pig Iron.* — The following table gives the production of pig iron in the United States in half-yearly periods from 1883 to 1905, in gross tons:

Years — Gross Tons	First Half	Second Half	Total
1883	2,352,019	2,243,491	4,595,510
1884	2,024,126	2,073,742	4,097,868
1885	1,920,371	2,124,155	4,044,526
1886	2,637,687	3,045,642	5,683,329
1887	3,049,295	3,367,853	6,417,148
1888	3,020,092	3,469,646	6,489,738
1889	3,661,603	3,942,039	7,603,642
1890	4,560,513	4,642,190	9,202,703
1891	3,368,107	4,911,763	8,279,870
1892	4,769,683	4,387,317	9,157,000
1893	4,562,918	2,561,584	7,124,502
1894	2,717,983	3,939,405	6,657,388
1895	4,087,558	5,358,750	9,446,308
1896	4,976,236	3,646,891	8,623,127
1897	4,403,476	5,249,204	9,652,680
1898	5,869,703	5,904,231	11,773,934
1899	6,289,167	7,331,536	13,620,703
1900	7,642,569	6,146,673	13,789,242
1901	7,674,613	8,203,741	15,878,354
1902	8,808,574	9,012,733	17,821,307
1903	9,707,367	8,301,885	18,009,252
1904	8,173,438	8,323,595	16,497,033
1905	11,163,175	.....	.....

Total Production of all Kinds of Pig Iron according to Fuel Used.*

	Blast Furnaces				Gross Tons of 2,240 lbs. (Includes Spiegeleisen, Ferro-Manganese, etc.)		
	In blast Dec. 31, 1904	June 30, 1905			First half of 1904	Second half of 1904	First half of 1905
		In	Out	Total			
Bituminous	206	229	82	311	7,337,279	7,594,085	10,162,488
Anthracite	38	42	23	65	622,803	605,337	830,175
Charcoal	17	23	33	56	213,356	124,173	170,512
Total	261	294	138	432	8,173,438	8,323,595	11,163,175

* "Bulletin," American Iron and Steel Association.

Coke Production in 1904. — Mr. Edward W. Parker, of the Division of Mining and Mineral Resources of the United States Geological Survey, reports a coke production during the calendar year 1904 of 23,621,520 net tons, valued at $46,026,183, or $1.948 per net ton. There were 83,499 ovens built and 4,430 building. To this production Pennsylvania contributed 14,861,-064 tons, or over 62 per cent. The productions of coke from by-product ovens amounted to 2,608,229 tons, or a little over 11 per cent of the total production. Of the completed by-product ovens in 1904, there were 895 Semet-Solvay, 1,795 Otto-Hoffman and Schniewind, 56 Newton-Chambers, 66 Wilcox and 98 Rothberg. The average production of the by-product ovens was 896 tons each, while the average production of the beehive ovens was 283.5 tons.

The British Iron Trade in 1904. — The following statistics are from the report of Mr. J. Stephen Jeans, secretary of the British Iron Trade Association:

Iron Ore. — The total production of iron ore in 1904 amounted to 13,774,282 gross tons, against 13,715,645 tons in 1903. The total imports of iron ore in 1904 amounted to 6,100,756 tons, against 6,314,162 tons in 1903.

Bessemer Steel Rails. — The production of Bessemer steel rails in 1904 amounted to 916,374 tons, as compared with 1,061,-441 tons in 1903 and 903,216 tons in 1902.

Puddled Bars. — The production of puddled bars in 1904 amounted to 936,228 tons, against 950,393 tons in 1903. The number of completed puddling furnaces in 1904 was 1,470, of which 1,166 were active in the year and 304 were idle.

Tinplates. — The production of tinplates in 1904 is estimated at 12,500,000 boxes, of which 8,000,000 boxes were for export and 4,500,000 boxes were for home consumption.

Iron and Steel Shipbuilding. — On December 31, 1904, the tonnage of iron and steel vessels under construction amounted to 1,049,860 tons, against 898,478 tons on December 31, 1903.

RECENT PUBLICATIONS

Les Aciers Spéciaux, Volume II, by Léon Guillet. 132 9 × 11-in. pages; numerous illustrations, mostly photo-micrographs. Paper covers. Vve. Ch. Dunod. Paris. 1905. Price, 10 francs. — This second installment of Mr. Guillet's important work dealing with special steels includes his papers on chromium, tungsten, molybdenum, tin, titanium, vanadium, aluminum and cobalt steel, which were originally published in the " Revue de Métallurgie " in 1904 and 1905. It will be remembered that the first volume, which was reviewed in *The Iron and Steel Magazine* for October, 1904, dealt with silicon, manganese and nickel steel. Like the first volume, the present one includes a preface by Prof. H. Le Chatelier. In his well-known researches the author considered especially the structure, tenacity, elastic limit, ductility, hardness (by Brinell's test) and brittleness (by the testing of nicked bars) of the steels which he studied. His experiments were conducted in a very systematic manner and included samples containing from 0.20 to 0.80 per cent of carbon and increasing proportions of the special element, in some cases up to 30 per cent. The value of Mr. Guillet's work needs no demonstration. Professor Le Chatelier does not hesitate to compare it to the classical researches of Sir Lowthian Bell on blast-furnace phenomena and to those of Hadfield on special steels. Metallurgists and engineers interested in these important steels are also under great obligation to the Steel Works of Imphy (France) and to the Dion et Bouton Company for the generosity with which the first-named provided the needed steels, and the latter the laboratory facilities, for their treatment and the study of their properties.

Procédés Métallurgiques et Etude des Métaux, by U. Le Verrier. 403 6½ × 10-in. pages; illustrated. Paper covers. Gauthier-Villars. Paris. 1905. Price, $3.60. — This is a recent volume added to the publishers, " Encyclopédie Industrielle "

series. The first part of this book deals with ores and metallurgical processes and contains chapters on sampling, dressing, drying, calcination and roasting, classification and description of furnaces, extracting methods, reduction, treatment of sulphide ores, distillation, electric processes, wet methods, smelting, refining, thermo-chemistry, metallurgical appliances; the second part is devoted to the physical testing of metals and to the influence of heat; the third part to metallography and the fourth part to alloys.

It will be seen that the subject covered is a very wide one and the author's treatment is necessarily general in its character. The usefulness of books dealing with the essential chemical, physical and mechanical features of metallurgy is not to be denied. The information conveyed by such treatises forms a safe foundation upon which to rest specialized studies; it constitutes the introductory knowledge which should be acquired before venturing into any special metallurgical field. Professor Le Verrier's book is a notable addition to metallurgical literature. We shall, however, venture the criticism that some of the photo-micrographs reproduced to illustrate types of structure do not seem to have been very well selected, while the poor quality of the paper used render some of them quite unintelligible, such being especially the case with the illustration on page 370.

Aids to the Analysis and Assay of Ores, Metals, Fuels, etc., by J. James Morgan. 105 4 × 6½-in pages. Baillière, Tindall & Cox. London. 1902. Price, 2*s.* 6*d.* — In this little book, which is for the first time brought to our attention, the author gives brief description of standard methods for the analysis of ores, metals, fuels, etc. In many instances only one method is given, while more than two methods are seldom outlined for any one determination, but those described appear to have been carefully selected. The special value of the book for ready reference lies in its condensed form, no fewer than 188 chemical determinations, covering a very wide metallurgical field, being described in less than 100 small pages.

The Journal of the Iron and Steel Institute, Vol. LXVII (No. 1, 1905). Edited by Bennett H. Brough, secretary. 865

4½ × 8-in. pages; illustrated. E. & F. N. Spon. London. 1905.—This volume, which, if we are not mistaken, contains more pages than any of those previously published, includes the minutes of the annual general meeting held in London in May, 1905, and the usual number of carefully compiled "Notes on the Progress of the Home and Foreign Iron and Steel Industries." A recent photograph of Right Hon. Sir Bernhard Samuelson, Bart., F. R. S., past president of the Institute, is reproduced as a frontispiece. The minutes of the proceedings include R. H. Hadfield's presidential address and the following papers with their discussions:

"The Continuous Steel Process in Fixed Furnaces." By S. Surzycki.

"Recent Developments of the Bertrand-Thiel Process in the Manufacture of Steel." By J. H. Darby and G. Hatton.

"Experiments Relating to the Effect of Mechanical and Other Properties of Iron and Its Alloys Produced by Liquid Air Temperatures." By R. A. Hadfield.

"The Applications of Dry-Air Blast" (supplementary paper). By James Gayley.

"The Cleaning of Blast-Furnace Gas." By Axel Sahlin.

"Experiments on the Fusibility of Blast-Furnace Slags." By O. Boudouard.

"Notes on the Failure of an Iron Plate through Fatigue." By S. A. Houghton.

"Accidents Due to the Asphyxiation of Blast-Furnace Workmen." By B. H. Thwaite.

"Sulphur in Coke, and Its Behaviour in the Blast Furnace." By F. Wuest and P. Wolff.

"The Types of Structure and the Critical Ranges on Heating and Cooling of High-Speed Tool Steels under Varying Thermal Treatments." By H. C. H. Carpenter.

"Magnetic and Electric Properties of Various Kinds of Sheet Steel and Steel Castings." By Gunnar Dillner and A. F. Enstrom. (Abstract.)

"Effects Caused by the Reversal of Stresses in Steel." By G. C. Gardner. (Abstract.)

"Troostite." By F. Rogers. (Abstract.)

"Heat Treatment and Fatigue of Steel." By F. Rogers. (Abstract.)

Elementary Microscopy, by F. Shillington Scales. 179 4 × 6-in. pages; 78 illustrations. Baillière, Tindall & Cox. London. 1905. Price, 3*s*. — This is essentially a handbook for beginners, the author confining himself to a clear and concise description of the optical principles involved in the construction of microscopes and of the manipulation required in their use. The book contains illustrations of the standard types of the best English microscope makers. The book is well printed on good paper and the illustrations are satisfactory.

The New Knowledge, by Robert Kennedy Duncan, professor of chemistry in Washington and Jefferson College. 263 4½ × 8-in. pages; illustrated. A. S. Barnes & Co. New York. 1905. Price, $2.00. — In this exceedingly interesting book the author attempts to present in a popular and yet strictly scientific manner, the recent contributions of such eminent physicists and chemists as Becquerel, the Caries, Ramsay, Crookes and others. The subject is sub-divided into seven parts, dealing respectively with Current Opinions, The Periodic Law, Gaseous Ions, Natural Radio-Activity, The Resolution of the Atom, Inorganic Evolution and New Knowledge and Old Problems, each part being in turn subdivided into several chapters. The author's style is clear and forceful and his book altogether delightful and singularly instructive reading.

A Technological and Scientific Dictionary. Parts I to IX inclusive. Edited by G. F. Goodchild and C. F. Tweney. Each part has 64 6 × 10-in. pages and is illustrated. George Newnes, Ltd. London. Price, each part, 1*s*. net. — This dictionary will be completed in fifteen parts and will then contain the definition of some 16,000 words used in pure and applied science, such as chemistry, physics, engineering, textile industries, architecture, etc. The dictionary includes special articles written by experts on important subjects, such as iron, steel, gas manufacture, boilers, steam engines, etc. It should be welcome by workers in pure as well as in applied science.

Statistical Abstracts of the United States, 1904. Prepared by the Bureau of Statistics, under the direction of the Secretary

of Commerce and Labor. 659 6 × 9-in. pages. Government Printing Office. Washington. 1905. — This is the twenty-seventh annual volume of statistical abstracts prepared by the Bureau of Statistics, and it contains the usual amount of valuable information referring to most of the natural and manufactured products of the United States during the last calendar year and many financial tables of the greatest value to those interested in the business condition of the country at large. The volume contains 203 statistical tables.

Society for the Promotion of Engineering Education, Vol. XII. Edited by C. F. Allen, F. W. McNair and M. S. Ketchum, committee. 254 6 × 8½-in. pages. Engineering News Publishing Company. New York. 1905. Price, $2.50. — This volume contains the proceedings of the twelfth annual meeting of the society, which was held at St. Louis September 1–3, 1904.

International Catalogue of Scientific Literature. Seventeen volumes, 8vo. Published for the International Council by the Royal Society, London. Harrison & Son. Price, £18. — This "International Catalogue of Scientific Literature," commencing with the literature of the year 1901, is an outgrowth of the "Catalogue of Scientific Papers Relating to the Scientific Literature of the Nineteenth Century," published by the Royal Society of London.

The possibility of preparing a complete index of current scientific literature by international coöperation was first taken into consideration by the Royal Society about the year 1893. The society sought the opinion of a very large number of representative bodies and individuals abroad; and, as the replies were almost uniformly in favor of the work being undertaken by international coöperation, an International Conference of Delegates appointed by various governments took place in London in 1896. It was unanimously resolved that it was desirable to compile and publish, by means of an international organization, a complete catalogue of scientific literature, arranged according both to subject matter and to authors' names, in which regard should be had, in the first instance, to the requirements of scientific investigators, so that these might find out, with a minimum of trouble, what had been published on

any particular subject of inquiry. It was agreed that the material should, as far as possible, be collected in the various countries by local organizations established for the purpose, and that the final editing and publication of the catalogue should be intrusted to a Central International Bureau acting under the direction of an International Council, and it was agreed to establish the Central Bureau in London.

At a subsequent meeting it was decided that the Royal Society be requested to organize the Central Bureau, and to do all necessary work, so that the preparation of the catalogue might be commenced in 1901.

The supreme control over the Catalogue is vested in an International Convention. Such a convention is to be held in London in 1905, in 1910, and every tenth year afterwards, to reconsider and, if necessary, to revise the regulations for carrying out the work of the Catalogue; but the approved schedules are not to be altered during the first period of five years. In the interval between two successive meetings of the convention, the administration of the Catalogue is vested in an International Council, the members of which are to be appointed by the Regional Bureaus.

The first meeting of the International Council was held in London on December 12, 1900, when it was decided to commence the preparation of the Catalogue from January 1, 1901. At this meeting an executive committee was appointed, consisting of the delegates of the Royal Society and representatives of the four largest subscribers,— the United States of America, Germany, France and Italy.

The materials out of which the Catalogue is formed are to be furnished by Regional Bureaus.

The branches of science to be included in the Catalogue are the seventeen following: A — Mathematics; B — Mechanics; C — Physics; D — Chemistry; E — Astronomy; F — Meteorology (including Terrestial Magnetism); G — Mineralogy (including Petrology and Crystallography); H — Geology; J — Geography (Mathematical and Physical); K — Palæontology; L — General Biology; M — Botany; N — Zoölogy; O — Human Anatomy; P — Physical Anthropology; Q — Physiology (including experimental Psychology, Pharmacology and Experimental Pathology); R — Bacteriology.

Each complete annual issue of the Catalogue will thus consist of seventeen volumes. The price at which this set will be sold to the public is £18. Individual volumes will be sold at prices varying with their size, from about 10 to 35*s*.

Each volume consists of three parts: (*a*) Schedules and indexes in English, French, German and Italian, (*b*) an authors' catalogue and (c) a subject catalogue.

The gigantic size of this undertaking will be readily appreciated as well as its undoubted value to scientific workers, but the high price at which it is apparently necessary to sell the volumes is much to be regretted, for it will be found prohibitive for a large number of interested persons. The Smithsonian Institution at Washington has undertaken the work of indexing the literature of the United States, and those desiring to become subscribers to the Catalogue should apply to that institution.

BOOKS RECEIVED

The following books have been received and will be reviewed in an early issue of *The Iron and Steel Magazine.*

Coke. A Treatise on the Manufacture of Coke and Other Prepared Fuels and the Saving of By-products, by John Fulton. 476 6 × 9-in. pages; illustrated. International Textbook Company. Scranton. 1905. Price, $5.00.

Mechanics of Materials, by Mansfield Merriman. Tenth edition, rewritten and enlarged. 507 6 × 9-in. pages; illustrated. John Wiley & Sons. New York. 1905. Price, $5.00.

Machine Shop Tools and Methods, by W. S. Leonard. 554 6 × 9-in. pages; nearly 700 illustrations. John Wiley & Sons. New York. 1905. Price, $4.00.

Laboratory Notes on Practical Metallurgy, by Walter MacFarlane. 140 5 × 7 in. pages; illustrated. Longmans, Green & Co. New York. 1905.

Laboratory Chemistry, by Richard B. Moore. 195 5 × 7-in. pages; illustrated. J. B. Lippincott & Co. Philadelphia. 1904. Price, 75 cents.

Metallurgy of Cast Iron, by Thomas D. West. Ninth edition. 677 5 × 7-in. pages; illustrated. The Cleveland Printing and Publishing Company. Cleveland, Ohio. 1904. Price, $3.00.

The Copper Handbook, by Horace J. Stevens, Volume V (1904). 882 6 × 8½-in. pages; illustrated. Houghton, Mich. 1905. Price in buckram binding, $5.00; in full morocco, $7.50.

The Crystallization of Iron and Steel, by J. W. Mellor. 144 4 × 7½-in. pages; illustrated. Longmans, Green & Co. New York. 1905. Price, $1.60.

Friction and Lubrication, by William M. Davis. Second edition. The Lubrication Publishing Company. Pittsburg, Pa.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

795,139. Blast Furnace. — Nelson M. Langdon, Mancelona, Mich.

795,193. Treatment of Chromiferous Iron. — Harry H. Campbell, Steelton, Pa.

795,218. Furnace for Treating Sheet Iron and Steel. — Harry H. Goodsell, Leechburg, Pa.

795,258. Gas-Producer Apparatus. — Carleton Ellis, New York, N. Y., assignor to Eldred Process Company, New York, N. Y., a corporation of New York.

795,275. Process of Manufacturing Portland Cement from Slag. — Carl von Forell, Hamburg, Germany, assignor to Henry Edmunds, London, England.

795,517. Process of Producing Tungsten Steels. — Edward D. Kendall, Brooklyn, N. Y., assignor of one half to Edward N. Dickerson, Stovall, N. C., and one fourth to Emmet R. Olcott, New York, N. Y.

795,643. Mold for Casting Rolls. — Frank M. Newingham, Apollo, Pa.

795,835. Gas-Producer. — William B. Hughes, Wissahickon, Pa.

795,842. Tuyere-Bushing. — Frank Klepetko, New York, N. Y.

795,907. Gas-Producer. — Henrich Gerdes, Berlin, Germany, assignor to American Suction Gas Producer Company, Lansing, Mich.

795,918. Gas-Producer. — Ernst Korting, Pegli, Italy.

798,242. Wire-Annealing Furnace. — John F. Warwick, Chicago, Ill.

798,258. Metallurgical Furnace. — George H. Benjamin, New York, N. Y.

798,500. Gas-Producer. — Carleton Ellis, New York, N. Y., assignor to Eldred Process Company, New York, N. Y., a corporation of New York.

GREAT BRITAIN

12,816 of 1904. Hardening Steel. — S. N. Brayshaw, Manchester. A bath for hardening steel, consisting of chlorides of potassium and sodium, with a small amount of ferro-cyanide of potash.

14,757 of 1904. Purification of Blast-Furnace Gas. — B. H. Thwaite, London. Improvements in the inventor's process for purifying blast-furnace gases and making them available for use in gas-engines.



ROBERT FORRESTER MUSHET

SEE PAGE 443

The Iron and Steel Magazine

" . . . . . Je veux au mond publier
d'une plume de fer sur un papier d'acier."

Vol. X November, 1905 No. 5

OVERHEATED STEEL *

By ARTHUR WINDSOR RICHARDS and JOHN EDWARD STEAD

Introduction

IN view of the fact that there still exists much confusion in the minds of many metallurgists as to the definition of the term overheating as applied to steel, and as to whether or not reheating overheated steel can invariably be relied upon to restore good properties to such brittle material, we venture to present a review of the opinions of those who have specially studied the question, and to supplement our previous work on this subject by further experiments in the hope that some of the confusion may be removed.

The pioneer work of Tschernoff, afterwards confirmed by Brinell and others, shows clearly the value of proper heat treatment in restoring forged steel, which had been made coarsely crystalline by heating at a high temperature, into material of finely crystalline character and good physical quality as was determined by the ordinary system of testing.

Professor Howe, in his " Metallurgy of Steel," states that " steel which has been exposed to a very high temperature is known as ' burnt.' It is cold-short and brittle, can be forged and welded only with care and has a low tensile strength. Its fracture is coarse and even flaky, crystalline, with brilliant facets. Steel known as ' overheated ' has a coarse structure, which may be removed more or less completely by reheating or careful forging. Excessively long or strong overheating pro-

* " Iron and Steel Institute," September, 1905.

duces the structure known as ' burnt,' and the coarseness and brittleness due to burning are removed with greater difficulty and much less completely than those due to overheating, yet in the same manner and by the same expedients."

The same authority, in his work on " Iron, Steel and other Alloys," states: " As a palliative for burning, mechanical refining by rolling, etc., is much more effective than heat refining, as we should naturally expect. For while heat refining should be powerless to close up even the most minute cracks, the compression and kneading which accompany mechanical refining should have a powerful effect in closing cracks even of considerable size, especially if their sides have not become coated with iron oxide."

William Metcalf, in his book, " Steel: A Manual for Steel Users," says: " A ' fiery ' fracture indicates too much heat. It may be found in the best steel and in the poorest; it may be corrected by simply heating to a proper temperature. It shows that some one needs to be reprimanded for careless work." He further states: " Actual burning reveals itself in rough tears and cracks at the surface and corners of the piece. Such a piece should go to the scrap-heap. Overheated steel of coarse, fiery grain has been injured, and not necessarily destroyed. Such a piece may be restored to any fineness of grain by heating to the right temperature — medium orange for the best grain — keeping it at that heat for, say, one minute for a little piece, and five to ten or fifteen minutes for a large piece. The heat should penetrate the whole mass, and it should not be allowed to run above the given color in any part, not even for a moment. It should then be allowed to cool in a dry place, without disturbance. The grain will now be fine and uniform, and the steel may be worked in the ordinary way. This simple operation is all that is necessary to restore to a fine grain any piece of steel that has been overheated, provided that the piece has not been actually burned nor ruptured." In the glossary at the end of Mr. Metcalf's book is given the following definition of overheating:

" *Overheated.* — Steel that has been heated too hot, and not quite burned; its fiery fracture exposes it. The grain of overheated steel may be restored, but restored steel is never as reliable as steel that has not been overheated. Overheating is a disintegrating operation."

A committee of the Iron and Steel Institute on the nomenclature of metallography define "overheated" (Ger. *Ueberhitzt*, Fr. *Surchauffé*) as "Applied to steel that has been heated to excess and not quite burned."

In Prof. Alfred Stansfield's paper on "The Burning and Overheating of Steel," * overheating is defined as "reheating to below the point of incipient fusion," and that "steel that has been merely overheated can be completely restored by heating just above its highest recalescence point and allowing to cool."

Professor Heyn, Mr. C. H. Ridsdale and one of the present authors have shown that overheated soft steel can be and is *completely restored* by reheating to a proper temperature above the point Ac3.

In the sixth report of the Alloys Research Committee, by Sir W. Roberts-Austen and Professor Gowland, there is evidence that overheated steel can be completely restored to good quality by reheating.

Professor Arnold, † in discussing the question of restoring the good properties by reheating brittle steel, claims that it was invented in Sheffield in 1820, but that those who were best capable of judging did not call it restoring but "*faking*."

Mr. Rogers' ‡ most valuable researches on "The Fatigue of Steel," a work which must be considered of the very highest value to engineers and metallurgists, indicates that steel with 0.27 per cent carbon, after overheating at 1215° C. for three hours and reheating to 900° C. for ten minutes and cooling in air, compared with the normal steel after annealing it at 655° C. for half an hour, was restored to a higher fatigue-resisting character. The results given are as follows:

	Normal Annealed at 6550° C. 17.78 Tons Fiber Stress	Overheated at 1215° C. 16 Tons Stress	Restored. 17.78 Tons Stress
Reversals to produce fracture..	1,493,600	636,950	2,692,700
Ratio	1	0.42	1.80

* "Journal of the Iron and Steel Institute," 1903, No. 2, p. 433.

† Sixth Alloys Research Report. Proceedings of the Institution of Mechanical Engineers.

‡ F. Rogers, "Heat Treatment and Fatigue of Steel." "Journal of the Iron and Steel Institute," 1905, No. 1, p. 486.

The bars as rolled, however, before annealing for a short time at 650° C., stood more fatigue than the restored steel, inasmuch as it took 2,630,100 reversals at 19 tons stress to produce fracture, while the restored steel broke down with 204,350 reversals at 19 tons stress.

The experience of all steel founders has proved beyond doubt that their castings, when they leave the molds, are very coarsely crystalline and more or less brittle, and that reheating to between 800° and 900° C. destroys the coarse crystallization and removes the brittleness. The physical character of overheated forged steel is identical with that of steel castings, excepting that the latter are liable to contain intercrystalline deposits. One would naturally expect that the same heat treatment would be followed in each class of material, with the same improvement.

It is well known that in the production of armor plates the steel, during its prolonged sojourn in the cementation furnace, becomes exceedingly coarsely crystalline and brittle, and in such condition may be regarded as overheated, and that by proper reheating the coarse brittle character is completely removed, and a steel of exceptional toughness produced.

Capt. H. Riall Sankey and Mr. J. Kent Smith in a recent paper * show that after overheating their chrome-vanadium steel at 1200° C. for twelve hours and reheating to 950° for half an hour the mechanical properties, according to all the tests applied, compared with those of the raw steel, were much improved.

In our previous paper † it was shown that, provided the heating was not carried to the point of disintegration, overheated steel could be completely restored to excellent quality, and made even superior to what it was in the forged condition.

In traversing the expressed conclusions of the authorities quoted it seems evident that both Professor Howe and Mr. Metcalf, although they are emphatic in their statements that "heat refining" removes coarse and produces fine crystallization, are not so strongly convinced that the steel will be com-

* "Heat Treatment Experiments with Chrome-Vanadium Steel." Proceedings of the Institution of Mechanical Engineers, 1904, p. 1319.

† "Restoration of Dangerously Crystalline Steel by Heat Treatment." "Journal of the Iron and Steel Institute," 1903, No. 2, p. 119.

pletely restored; indeed, Metcalf states that " restored steel is never so reliable as steel which has not been overheated." The remark, however, that " overheating is a disintegrating operation " clearly shows that what is meant here by overheating is incipient disintegration.

Professor Stansfield's simple definition of overheating is practically that which we hold, qualified by the obvious inference that until the point of incipient fusion is reached there cannot be any disintegration.

High-carbon crucible steels, such as were available at the time when Mr. Charles Wardlow made his experiments in Sheffield in 1820, are very easily incipiently disintegrated by heat, as is proved by the fall in the specific gravity produced by high heating. Reheating will not perfectly restore it unless it is forged to a smaller size, and not even by forging if the steel has suffered severe disintegration.

The confusion existing appears to have arisen by confounding " burnt " with " overheated " steel, and it certainly seems to us that this will disappear if the following definitions of overheating and burning are accepted, viz.:

Overheating is heating at any point below that which produces incipient disintegration and results in the formation of large crystals.

Burning is heating at or above the point at which such disintegration occurs; burnt steel is nearly always coarsely crystalline.

If these definitions are accepted, the following facts should be remembered:

(1) That all overheated steel is more or less coarsely crystalline.

(2) That different steels, apparently of the same composition, vary in their susceptibility to disintegration. At a given high temperature one may be simply overheated whilst another may be burnt and partially disintegrated.

(3) That burnt steel cannot be completely restored by reheating; it can be greatly improved, but is never equal to reheated steel which has not suffered partial disintegration.

As an example of such burnt steel before and after heat treatment photomicrographs, Figs. 4 and 5, are given, in which

it is shown that some of the broad ferrite sheets or bands remain after reheating, and these are divided centrally by some substance quite foreign to the steel proper. On attempting to bend this steel the ferrite bands broke up along the line or plane of the foreign substance, and this, of course, led to sudden fracture through the whole mass. Such burnt steel is only fit for the scrap-heap or remelting; it is worthless until it has again passed through the fluid state.

General Description of Work Done

In this research, instead of working upon rails we have mainly confined our work to the treatment of 1-inch square rolled bars. The tests applied were as follows:

(1) Testing for maximum tenacity and elongation in a 50-ton Buckton machine having a hydraulic cylinder driven from an accumulator and belt-driven pump coupled to a motor running at a constant speed.

The yield point was observed by means of a pair of callipers adjusted to suitable marks on the test-piece. The diameter of the bars, turned parallel, was 0.75 inch, and the portion subjected to tension 4 inches in length.

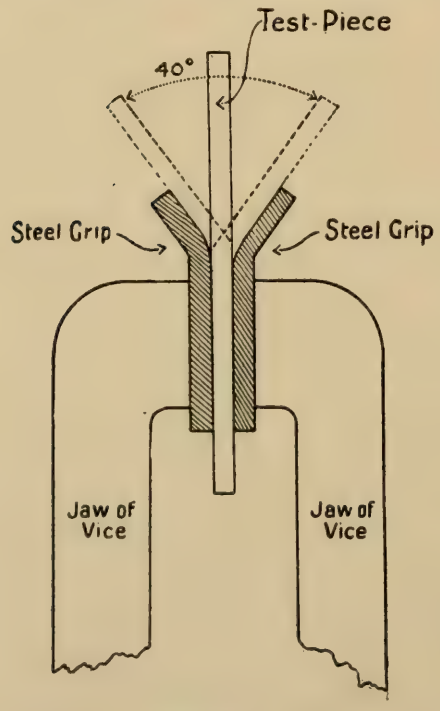


Fig. 1. Bending to Fracture

(2) Ordinary bending tests. The pieces tested were cut from the bars and were highly polished, being of the following dimensions:

Length, 100 mm.; breadth, 6 mm.; thickness, 3 mm.

The measurements recorded in the table of tests represent the radius of the convex side of the bend when fracture occurred.

It will be understood that the greater the radius the less ductile the steel, and *vice versa*.

(3) Alternate bending of strips, having a section 6 mm. × 3 mm., through an angle of 40°. The number of bendings backward and forward to produce fracture was recorded in each case. (See Fig. 1.)

(4) Rotary bending through a constant slight angle, of round pieces of the same dimensions as those used for fiber stress testing described in (5).

(5) Testing by reversals of stress, by the Wöhler method, on a machine built by Messrs. Richardson, Westgarth & Company to designs supplied by us, it being an improved form of that described in our previous paper. (See Fig. 2.)

The machine consists of a strong steel spindle on which is mounted three pulley wheels, giving speeds of 800, 1,200 and

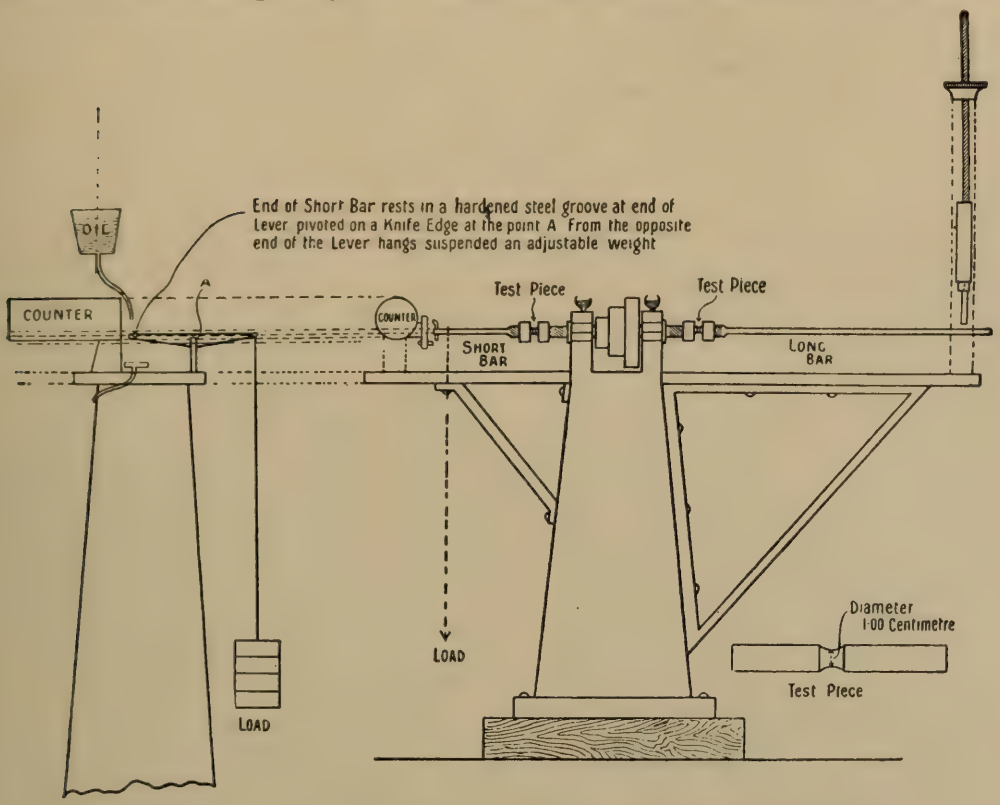


FIG. 2. Richards and Stead's Machine for Testing Steel by Reversal Stress and Strains

2,400 revolutions per minute when driven by a suitable motor. The spindle moves in massive bearings, and each end terminates in a modified form of self-centering chuck in which the test-pieces are securely fastened.

To one end of the machine is attached a short steel bar 10 inches long, also with suitable chuck, which is connected to the spindle by the test piece, one end of the bar running free, and having a groove in which is loosely fitted one end of a hardened steel lever carrying the load used in testing. The other end of

the machine is similarly fitted, the bar being 42 inches long, and

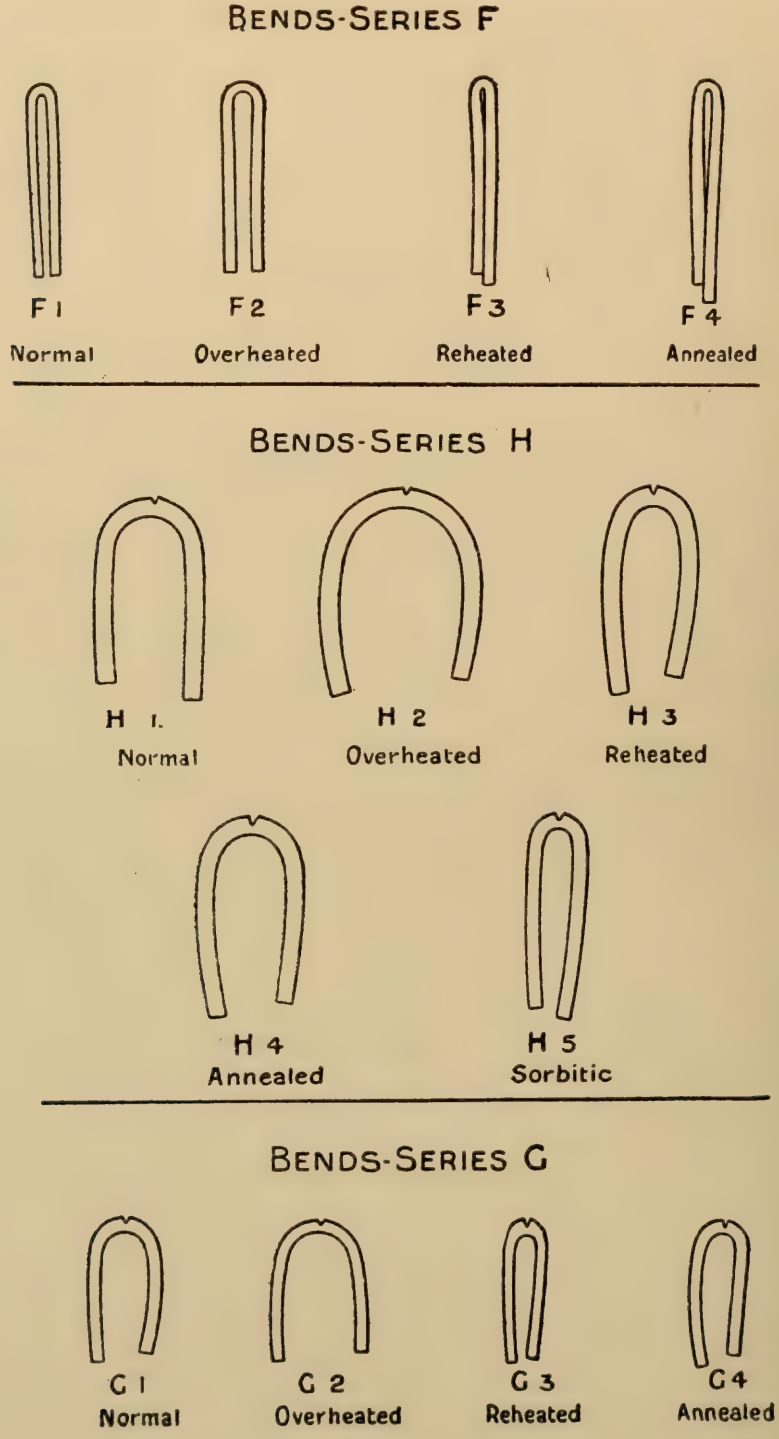


FIG. 3

the load is applied by means of a spring balance, following the plan of Professor Ewing and Mr. Humfrey. A suitable counter

for recording the number of revolutions is also attached. (See Fig. 3.)

The test pieces were uniform in size, being 4 inches long, and turned to a diameter of one-half inch, the center of each being further reduced by a semicircular groove to a diameter of exactly 1 cm. (See Fig. 3.)

Analysis of Steels

	Series F Per cent	Series G Per cent	Series H Per cent
Combined carbon	0.06	0.48	0.44
Manganese	0.20	0.82	0.80
Silicon	0.02	0.045	0.02
Sulphur	0.05	0.06	0.064
Phosphorus	0.032	0.087	0.054

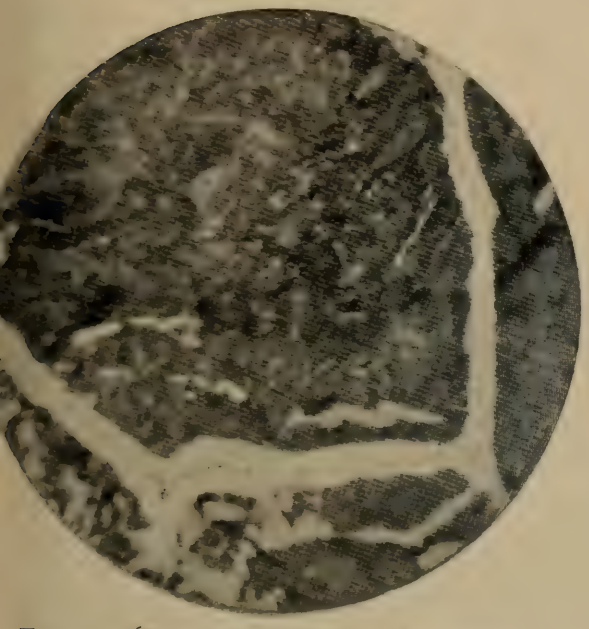


FIG. 4. Burnt Rail Steel. Magnified 50 diameters.

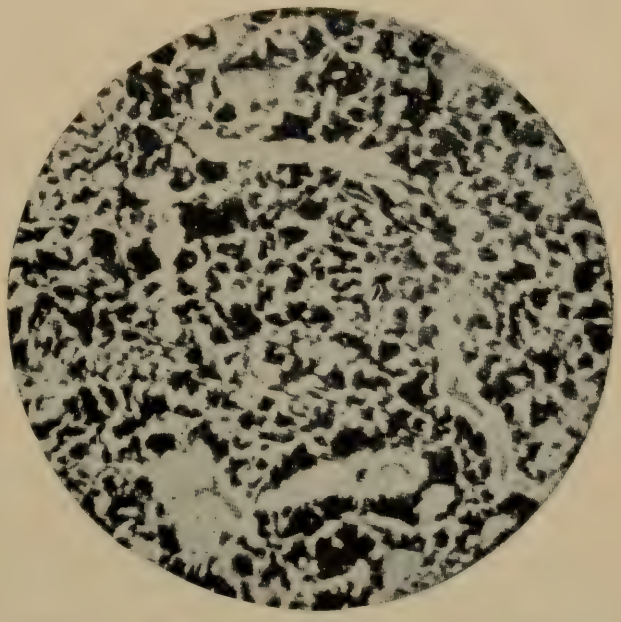


FIG. 5. Burnt Rail Steel. Same as Fig. 4, after reheating to and cooling from 850° C. Magnified 50 diameters.

DESCRIPTION OF TREATMENT AND OF THE TERMS USED

(1) *Normal Steel.* — Bars tested in the condition as received from the rolls.

(2) *Overheating.* — The bars were packed in quartz sand in a closed firebrick tube and heated at a temperature of about 1300° C. for from two to three hours. The tube with contents was allowed to cool in air before opening.

(3) *Reheating.* — The overheated steels were packed in a closed firebrick tube and heated in a muffle furnace until a temperature of 880° C. was reached, with the exception of Series F, which were heated to 950° C. The tubes with their contents, as soon as the desired temperature was reached, were removed and allowed to cool in air before opening.

(4) *Annealing.* — The rolled bars were slowly heated in a muffle furnace to a temperature of from 850° to 880° C., with the exception of Series F, which was heated to 950° C., and were then withdrawn and allowed to cool in air.

(5) *Sorbitic Treatment.* — Portions of the rolled bars of Series H were heated to 900° C., quenched in cold water and afterwards reheated to 330° C. for twenty minutes and allowed to cool in air.*

Tensile Tests

Series		Yield Point. Tons per Square Inch	Ultimate Stress. Tons per Square Inch	Ratio of Yield Point to Ultimate Stress. Per Cent	Elongation. Per Cent in 4 Inches	Contraction of Area. Per Cent
F 1	Carbon, 0.06 per cent normal . . .	16.05	24.40	65.70	35.00	66.30
F 2	,, ,, overheated	14.75	23.80	62.00	33.00	60.80
F 3	,, ,, reheated .	15.85	24.20	65.50	40.00	67.10
F 4	,, ,, annealed .	15.65	23.60	66.30	37.00	70.90
G 1	Carbon, 0.48 per cent normal . . .	27.20	45.80	59.70	19.00	34.50
G 4	,, ,, overheated	27.40	46.90	58.50	10.00	26.50
G 3	,, ,, reheated .	27.00	45.80	59.00	22.00	38.60
G 2	,, ,, annealed .	22.00	48.30	55.30	21.00	36.50
H 1	Carbon, 0.44 per cent normal . . .	21.70	40.20	53.80	23.00	48.80
H 2	,, ,, overheated	20.60	41.30	52.40	12.00	20.60
H 3	,, ,, reheated .	22.00	40.20	54.70	25.00	51.10
H 4	,, ,, annealed .	21.30	39.90	53.40	24.00	50.00
H 5	,, ,, sorbitic . .	43.40	55.10	78.70	25.00	56.80

Ordinary Bending Tests

Section of bars 6 mm. by 3 mm.

		F	G	H
Normal	radius of bend	6.50	7.25	8.00 mm.
Overheated	,, ,,	7.00	10.80	12.20 ,,

* Although this treatment is very liable to produce water cracks, none were produced in our experiments. Further trials are in progress to ascertain the best possible method of producing sorbitic steel.

		F	G	H
Reheated	radius of head	6.00	6.65	6.40 mm.
Annealed	,, ,,	6.00	6.80	7.00 ,,
Sorbitic	,, ,,	..	..	6.00 ,,

(See Fig. 3.)

At 6 mm. radius the bends were quite close on the concave side.

Alternate Bending of Strips through an Angle of 40 Degrees

Series		Average Bends to Produce Fracture	Comparison. Normal = 1
F 1	Carbon, 0.06 per cent normal	48	1.0000
F 2	,, ,, overheated..	36	0.7500
F 3	,, ,, reheated ...	53	1.1041
F 4	,, ,, annealed ...	52	1.0833
G 1	Carbon, 0.48 per cent normal	115	1.0000
G 2	,, ,, overheated..	51	0.4434
G 3	,, ,, reheated ...	116.3	1.0113
G 4	,, ,, annealed ...	115.3	1.0026
H 1	Carbon, 0.44 per cent normal	117	1.0000
H 2	,, ,, overheated..	72	0.6125
H 3	,, ,, reheated ...	132	1.1271
H 4	,, ,, annealed ...	129	1.1000
H 5	,, ,, sorbitic	263	2.2444

Resistance to Alternating Fiber Stresses

Revolutions per minute, 1,200

Series		Total Revolutions to Produce Fracture	Comparison. Normal = 1	Fiber Stress
F 1	Carbon, 0.06 per cent normal ...	13,560	1.0000	25 tons
F 2	,, ,, overheated	9,760	0.7197	25 ,,
F 3	,, ,, reheated .	14,500	1.0693	25 ,,
F 4	,, ,, annealed .	14,200	1.0471	25 ,,
G 1	Carbon, 0.48 per cent normal ...	83,550	1.0000	28 tons
G 2	,, ,, overheated	38,660	0.4627	28 ,,
G 3	,, ,, reheated .	111,500	1.3226	28 ,,
G 4	,, ,, annealed .	103,130	1.2344	28 ,,
H 1	Carbon, 0.44 per cent normal ...	1,432,500	1.0000	25 tons
H 2	,, ,, overheated	844,950	0.5891	25 ,,
H 3	,, ,, reheated .	2,080,440	1.4528	25 ,,
H 4	,, ,, annealed .	1,971,000	1.3773	25 ,,
H 5	,, ,, sorbitic ..	3,517,200	2.4570	25 ,,

Rotary Bending through an Angle of 6 Degrees

Revolutions per minute, 1,200

Series		Total Revolutions to Produce Fracture	Comparison. Normal = 1
F 1	Carbon, 0.06 per cent normal	3,500	1.0000
F 2	,, ,, overheated..	2,590	0.7400
F 3	,, ,, reheated ...	3,730	1.0655
F 4	,, ,, annealed ...	2,680	1.0510
G 1	Carbon, 0.48 per cent normal	3,940	1.0000
G 2	,, ,, overheated..	2,040	0.5177
G 3	,, ,, reheated ...	5,300	1.3451
G 4	,, ,, annealed ...	5,120	1.3000
H 1	Carbon, 0.44 per cent normal	3,660	1.0000
H 2	,, ,, overheated..	2,207	0.6306
H 3	,, ,, reheated ...	5,390	1.4731
H 4	,, ,, annealed ...	5,215	1.4255
H 5	,, ,, sorbitic	9,280	2.5361

In reviewing the results of our experiments, what appears to be most remarkable is the fact that the indications obtained by all systems of testing prove that overheating reduces the power of the steel to resist fatigue; that reheating such steel more than restores the original good qualities of the rolled bars, and that when the steel has the carbon in the sorbitic condition its power of endurance is more than doubled.

The results amply confirm those published in our previous paper, " Heat Treatment of a Broken Axle " (Series 1).

By the kind permission of Mr. James Holden of the Great Eastern Railway Company we are able to describe experiments made to determine the effect of heat treatment on a wagon axle which broke at a flaw after being in use for twenty years. The microstructure indicates that it had been initially slightly overheated. The analysis made by Mr. J. H. D. Jenkins, chemist to the Great Eastern Company, of a portion of steel cut from the axle was as follows:

Carbon	0.349 per cent
Manganese	0.837 ,,
Silicon	0.053 ,,
Sulphur	0.047 ,,
Phosphorus	0.085 ,,

Portions were cut from the axle under the wheel seating, where the stresses during the life may be assumed to have been inappreciable, and from near to the central axis where the fatigue stresses must have been at a maximum and near to where the fracture occurred. One portion of each was reheated in a muffle furnace to 820° C. and was cooled in air; these, with other untreated portions, were tested in a tensile testing machine at the Stratford works of the Great Eastern Railway Company with the following results, viz.:

Tensile Test

	Central Axis		From under Seating. Untreated	Wheel Reheated at 820° C.
	Untreated	Reheated at 820° C.		
Ultimate stress	37.83 tons	39.28 tons	38.31 tons	39.71 tons
Elongation per cent in 3 inches.....	27.08 per cent	29.17 per cent	27.08 per cent	28.12 per cent
Reduction of area per cent	47.37 „	49.68 „	45.15 „	50.32 „

Small pieces from each portion were treated as described below, and were subjected to continuous reversals of fiber stresses in the machine described in our previous paper.

Resistance to Reversals of Stresses

SAMPLES FROM CENTRAL AXIS

	Alternation of 19 Tons Fiber Stress
Normal	311,400
Reheated to 820° C. and cooled in air	1,506,000
Reheated to 850° C. and cooled in air	2,526,000
Reheated to 870° C., cooled in air, and reheated again to 850° C. and cooled in air..	13,532,000

SAMPLES FROM UNDER WHEEL SEATING

Normal	(*a*) 616,000 (*b*) 208,000
Reheated to 820° C. and cooled in air	1,052,000
Reheated to 850° C. and cooled in air	13,630,000
Reheated to 870° C., cooled in air, and reheated again to 850° C. and cooled in air	11,630,000 at 19 tons. 2,833,000 at 21 tons.

In each case the pieces of metal reheated did not weigh more than four ounces, the heating was rapidly effected and as soon

as the desired temperature was reached they were removed from the furnace. It is probable that a longer heating at somewhat lower temperatures would have given equally good results.

As the pieces heated were small, and the cooling necessarily comparatively rapid, the treatment may be regarded as approaching that of oil tempering on large masses.

In reviewing the known data received from Mr. Holden about this axle, together with the information obtained by our own testing, the following observations should be noted, viz.:

(1) The axle stood twenty years before it finally broke.

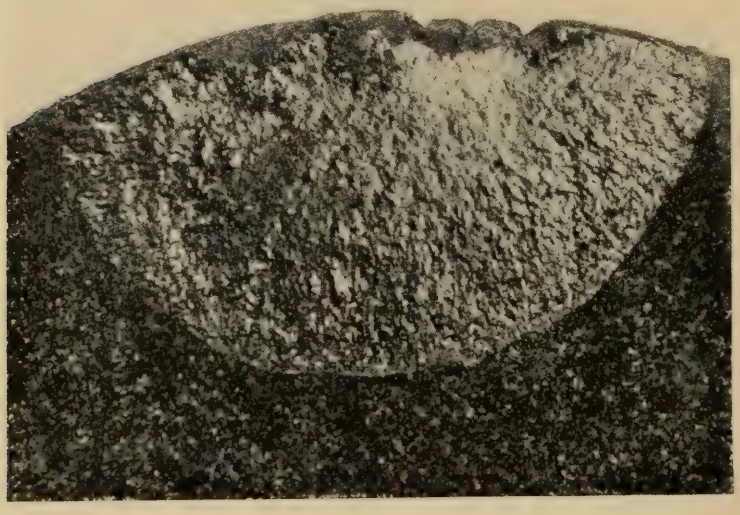


FIG. 6. Fractured Axle. Magnified 1½ diameters. Supplied by Mr. J. H. D. Jenkins.

During this period it had traveled probably 300,000 miles, and had been subjected to 200,000,000 reversals of stress.

(2) The flaw which initiated fracture appears to have been a deep stamp mark, clearly seen in the photograph supplied by Mr. Jenkins (Fig. 6).

(3) The weakness produced initially by this deep impression, in our opinion, eventually led to a fatigue fracture, which traveled from the upper to the convex termination of what corresponds with the light part shown in the photograph. Sudden or granular fracture followed through the remaining part of the mass.

(4) The inference is that had there been no such excessively deep stamp impression the axle could not have failed.*

(5) According to the fiber stress testing, the normal steel of rather coarse crystalline structure is relatively weak, but, for all that, it is good material, and calculated to be quite strong enough to stand all the normal working stresses.

(6) Proper heat treatment very greatly increases the fatigue-resisting properties of the steel.

(7) That ordinary tensile tests which do not show the yield points fail to give a hint as to the relative value of steels in their power to resist fatigue.

The photomicrographs, Figs. 8 and 9, represent the structure of the steel before and after heating to 870° and 850° C.

Hypothetical Conclusions

It is impossible to refrain from endeavoring to explain how it is that overheated steel should be so weak and non-resistant to the continued application of reversals of stresses and strains as compared with the same material in the normal and restored conditions. In doing this the following facts must be taken as bases, viz.:

(1) That in the normal and restored material the crystalline structure is in each case fine, whereas it is coarse in the overheated steels.

(2) That in Series G, H and I the crystal grains of large dimensions in the overheated steels were surrounded by more or less complete envelopes of massive free ferrite, and that in Series I the grains enclosed by these envelopes were cut up by plates or sheets of the same substance.

(3) That on bending the polished and etched specimen of the overheated steel backward and forward it was easily observed under the microscope that the extension or distortion during the bending was mainly confined to the massive ferrite envelopes and sheets. At first they appeared to sink below the surface, and eventually developed into actual fissures or incipient cracks;

* It may here be mentioned that, in the experience of one of the authors, this weakness and eventual fracture in axles is not by any means uncommon as the result of a deep stamp indentation. Such indentations are the exact equivalents of flaws, but instead of being accidental are deliberately produced.

an observation confirmed by Mr. Jenkins in the case of the broken axle.

(4) The researches of Professor Ewing, Messrs. Humfrey, A. E. Seaton * and A. Jude have proved that fracture of steel, when under the influence of long-continued fatigue or under sudden shock, is initiated in the free ferrite, and generally travels continuously as far as possible along a track in which there is the greatest amount of that constituent, in fact along the line of least resistance.

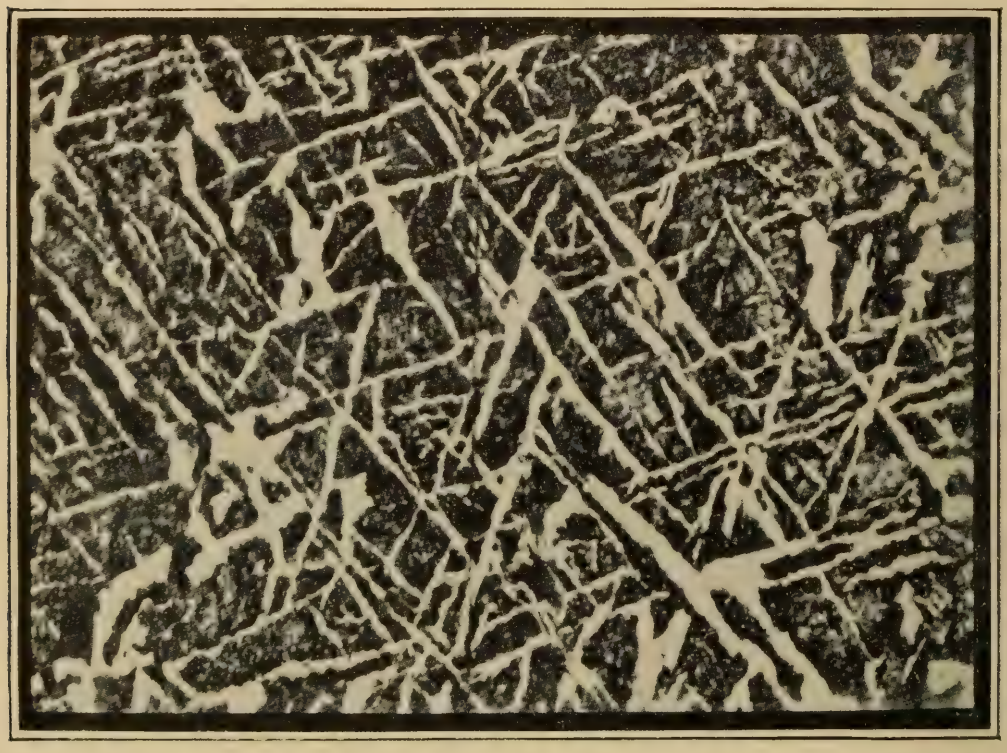


FIG. 7. Portion of Broken Axle; central part of one of the large grains. Photo supplied by Mr. Jenkins. Magnified 150 diameters.

(5) That in pure or nearly pure commercial carbon steels the ferrite has a yield point of probably not more than 8 to 12 tons per square inch, whereas the other constituent, pearlite, does not sensibly yield until a tension of about twice these amounts is reached, excepting when its structure is composed of broad sheets of ferrite and carbide of iron, for in such case the

* "Impact Tests on Wrought Steels of Commerce." Proceedings of the Institution of Mechanical Engineers, 1904, p. 1135.

ferrite behaves as if it were massive, and the yield point is necessarily much lower.

(6) The weakness of a steel under stress in any given direction depends on the manner in which the ferrite and pearlite are arranged with relation to the stresses applied. For instance, in large forgings it not infrequently happens that the ferrite and pearlite are arranged in more or less continuous bands or sheets. If a polished and etched section is bent slightly at right angles to the plane of these, and is then examined, it will be found that the ferrite bands are depressed below the surface, whilst the lines of pearlite remain in relief. On attempting to

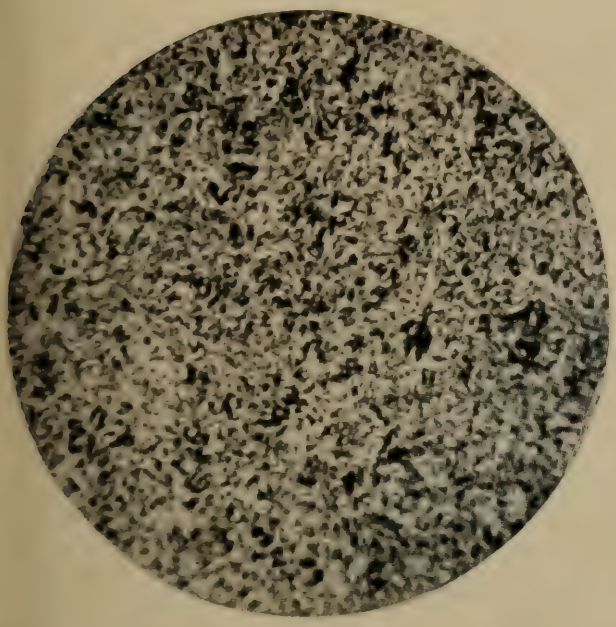


FIG. 8. Broken Axle after Heat Treatment; section cut from a fatigue test piece. Magnified 50 diameters.



FIG. 9. Broken Axle in Normal State; section cut from a fatigue test piece. Magnified 50 diameters.

bend to any great extent, the piece will break at a very poor angle. If, however, bending is effected with the fiber, the steel will bend quite close without fracturing. If such a steel is heated to a sufficient temperature so as to cause the carbon to be regularly diffused through what was originally massive ferrite, and it is then quenched in water and reheated to 650° C., it will bend close equally in each direction, provided that there is a complete absence of strings or plates of sulphide or silicate of manganese.

To make the point clearer by a hypothetical case, let us assume that a bar of pearlite is divided midway between its ends by a plate of ferrite 1-10 inch in thickness, and is perfectly united with the pearlite on each side of it. If this bar were to be submitted to tension, the ferrite would begin to extend and sink below the surface, and when it had extended as far as its nature would admit, it would break before the elastic limit of the pearlite was reached. The extension of the whole bar would be very slight, but that of the ferrite plate would be probably 20 per cent or more. The tenacity would be that of the ferrite. In such a case the ferrite would be the exact equivalent to the weakest link in a chain.

With these facts before us, it is not difficult to explain the weakness of coarsely crystalline structural steels. The comparatively massive and continuous sheets of ferrite approach more or less nearly to the actual and supposititious cases referred to of ferrite between pearlite. When under stresses which are below the yield point as determined by the testing machine, but which cannot be below that of the ferrite, they are concentrated on these broad bands, movements backward and forward, with each reversal of stress, occur between the particles of the soft ferrite, till eventually incipient fracture is started, and, once begun, it rapidly travels through ferrite and pearlite alike until a complete separation of the mass is effected. One broad plate of ferrite with planes at right angles to the direction of tension and compression will be sufficient to initiate fracture, and after this has actually broken there will be a very weak place where the stresses will be mainly concentrated, and the crack will grow to complete fracture.

In this way is explained why it is that the steel immediately adjoining a fatigue fracture is usually found to be practically as good as it was when first put in. The stresses soon find out the weak spot, and make it weaker and weaker by being continually concentrated there, whilst the adjoining steel is often practically not affected or weakened.*

In the case of overheated steels containing above 1 per cent carbon, the brittle envelopes of carbide of iron which surround the grains or which pass through their substance are the places along which fracture most readily travels.

* There are, as we have proved, exceptions to this rule.

Overheated steels consisting entirely of pearlite are very brittle, and probably fracture is initiated in the plates of carbide.

Ingot iron may be made coarse grained and brittle by long-continued heating at temperatures below Ac3–870° C., if the carbon is very low, and if it exceed 0.10, by heating at a very high degree of heat. In either case the steel is weak, and fracture is initiated between the cleavage planes of the ferrite when subjected to stresses and strains.

On the other hand, when the crystals are fine and the ferrite exists in minute crystals and are heterogeneously oriented and are intimately distributed with the pearlite throughout the mass, the strength of the two constituents is averaged, the lines of stress pass over a multitude of each of them, and the pearlite being the stronger, supports the ferrite and prevents it breaking down.

If these conclusions are right, it seems obvious that it would be an ideal condition if free ferrite were absent in carburized steels which have to be subjected to severe vibratory stresses. Ordinary structural steels in this condition can be obtained by heating to a suitable temperature, quenching and reheating at a lower temperature. The example described above as sorbitic steel was prepared in that way. It was devoid of free ferrite, and it will be seen that it has double the resisting power of the normal forged bars.

Before concluding we wish to emphasize the fact that we do not maintain that steel initially bad, brittle and dangerous, owing to irregularity in the distribution of the elements, or from other causes which have not yet been explained, can be made good by any kind of heat treatment. What we believe has been proved conclusively is that good steels which have been heated to any point short of incipient disintegration, and made excessively brittle by such treatment, can be completely restored to perfectly sound and reliable material. Also, that it is safest to heat to a temperature about 50° above the critical points to insure the complete change of every portion of the steel, excepting in the case of the purest and most homogeneous steels, when the temperature of the upper critical points need not be greatly exceeded.

In conclusion, we gratefully acknowledge the assistance of Messrs. Bolckow, Vaughan & Company, Ltd., who have en-

couraged our research, of Mr. James Holden of the Great Eastern Railway Company, and his chemist, Mr. Jenkins, for their contribution and permission to publish the experiments made on a wagon axle.

We must also acknowledge the valuable services of Mr. R. C. V. Whitfield, who is responsible for practically all the experiments on heat treatment and the mechanical testing.

NEW GIN PROCESS FOR THE ELECTRICAL MANUFACTURE OF STEEL*

By GUSTAVE GIN

THE new electric furnace which I have devised for the electrical manufacture of steel allows of the simultaneous and uninterrupted realization of the following operations:

Fusion, oxidation of impurities, reduction of dissolved oxide of iron, recarburization or introduction of the constituent elements of the final steel.

The accompanying design represents, to call it an example, one form of construction of a furnace accomplishing the conditions indicated.

Fig. 1 is the plan of the furnace.

Figs. 2 and 3 are transverse sections.

The furnace comprises essentially:

1. A crucible for fusion and refining by oxidation (1).
2. A compartment for reduction and recarburization (2).
3. A chamber for the observation of the color.

The electrodes of compartment (1) are connected to one of the terminals from the source of electricity, and the electrodes of compartments (2) and (3) are connected in parallel with the other terminal.

The current passes from the electrodes to the metal through a sheet of slag, which is the principal seat of the heating action of the current.

The baths of metal communicate by the openings (B) of sufficiently reduced section, in order that by reason of the Joule effect the metal may not remain solid.

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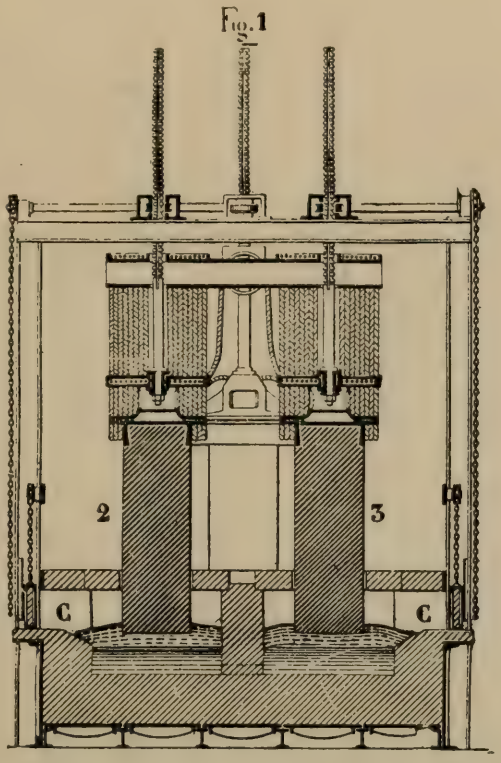
* American Electrochemical Society, Bethlehem, Pa., meeting, September, 1905.

The fitting of the compartments is appropriate to their function: The base and sides of the oxidation compartment (1) are, in the part permanently occupied by the metal, constructed of a material basic or acid, according as the metal to be refined is or is not phosphatic; but the part in contact with the slag should be neutral, of chromite of iron, for example.

In compartments (2) and (3) magnesia is employed preferably for the floor and surfaces not touched by the slag, and chromite of iron is made use of for the upper part.

To put the furnace into operation, melted iron or liquid steel is introduced through the orifice (A). It distributes itself through the three compartments, on the floors of which scrap iron is strewn, the pieces being placed in connection with (B). Then arcs are created and little by little the material is introduced, which, after fusion, forms the superficial baths in which the Joule effect is produced.

Fig. 1



The oxidizing bath of compartment (1) is composed of some mineral or slag rich in oxide of iron, in addition some lime if the metal to be refined is phosphatic. The baths of compartments (2) and (3) are neutral and little reducible by carbon.

Aluminates of lime and magnesia, made from a mixture of bauxite, with limestone or dolomite, give favorable results. The addition of calcium fluoride makes it more fusible and mobile.

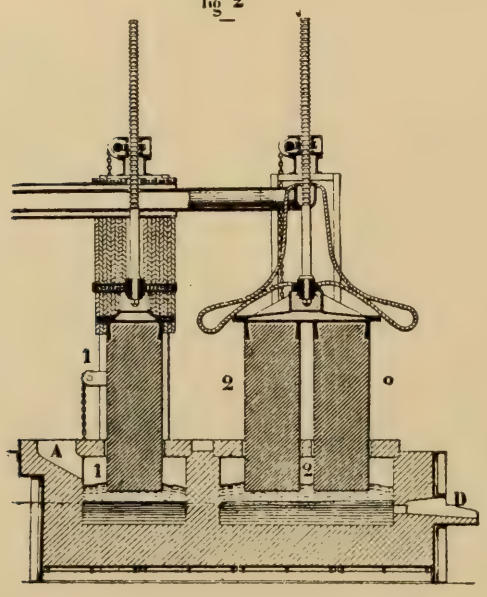
The functions of the furnace are characterized as follows: In the oxidation chamber the zone of most intense heat is, of course, found close to the contact of the metal and slag, and it is in this region that the reduction of the oxides is effected at the expense of the silicon, and of the manganese and carbon of the metallic bath.

According to the proportion of reducible oxides, the reaction is more or less rapid, and is evidenced by the turbulence of the bath, which stirs the metal and aids the oxidation by constantly changing the surface of contact. The oxidizing action is kept going and its intensity and rapidity regulated by the careful introduction of oxide of iron or by stirring.

Because of the high temperature, the elimination of the carbon is effected almost at the same time as that of the silicon and manganese.

By means of the method of circulation adopted, the refined metal in (1) passes next into compartment (2), where the reduction of the dissolved ferric oxide and the recarburization of the metal takes place. Thus two operations are accomplished entirely by the admission of carbon in the form of coke, of iron or of casting specially prepared by the fusion of iron or steel in the electric furnace in the presence of a great excess of carbon. In raising the metal to a sufficient temperature, a cast iron is obtained which absorbs as high as 7.7 per cent of carbon, which it retains on cooling, partly as combined carbon and partly as intermingled graphite. It may be advantageous to introduce this carbureted cast iron in the liquid state, as when it comes out of the electric furnace.

Fig. 2



The regulation of the recarburization or the incorporation demanded by the nature of finished steel, is accomplished in compartment (3), where some test ports are placed which allow one to estimate the color obtained and indicate additions to be made in correcting for impurities observed.

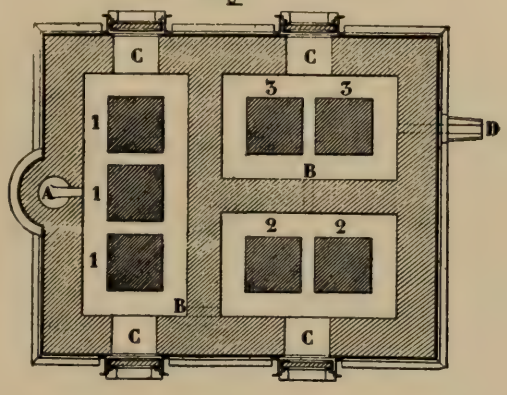
The necessary use in the Martin furnace of ferro-manganese or ferro-silicon, to prevent the oxidation of the metal before the purification, would be almost useless here. In fact, in the two last compartments the steel escapes all oxidizing action, for it

has no contact whatever with the atmosphere, and only comes in contact with a neutral slag. Besides, this slag under the influence of the high temperature and the presence of carbon furnishes a slight quantity of aluminum, which diffuses into the bath of steel and absorbs oxygen in whatever form it might be present.

The charging of the solid material and the withdrawal of the slag is effected by means of the openings (C) and the stream of steel by the orifice (D) placed at a given height above the floor.

To tap the metal, the electrodes (3) are lowered and immersed in the metallic bath at the same time that the electrodes (1) are raised, in order to maintain the voltage of the system. During the pouring, the immersion of the electrodes (3) is increased in such way that the level of the metal remains constantly at the height of the pouring orifice. After the electrodes touch the bottom of the crucible, as the level of the metal can no longer be maintained, the latter falls until the slag appears in the flowing jet, which is then stopped.

Fig. 3



The operation which has just been explained is of considerable importance. In fact, the immersion of the electrodes prevents unequal levels between the compartments (2) and (3). There can be no mixing of the metals at the different stages of the refining, and metal can only be run off when refined thoroughly and to a known color.

The duration of the pouring being nearly constant, the dissolution of carbon through the immersion of the electrodes varies little, and it is possible to keep careful account and guarantee for the final product a determined color within narrow limits.

After tapping, electrodes (3) are raised again and electrodes (1) are immersed in the metal; part of the metallic oxide passes from (1) into (2), while the carbureted steel in (2) penetrates into (3). Thus the levels remain at their normal height, the electrodes immersed in (1) occupying simply the place of the steel which has just been left. If at this moment we tap the crude iron or incompletely refined steel in the first compartment,

raising simultaneously electrodes (1), the metal introduced fills the space given by removal of the electrodes, but without ability to penetrate directly into compartment (2), for there is no sensible difference of level. The operations remain there distinct and independent and can succeed each other in continued rotation as long as the material retains sensibly the temperature of reduction, the capacity of the compartments being such that each tapping only represents a fraction of the metal present, the part remaining playing the part of a heat retainer.

Finally, it can be remarked that the metal in (1) passes to (2) without carrying the slightest trace of slag, which excludes all outside impurities.

STEEL AS AN IGNEOUS ROCK *

THE days in which steel was practically regarded as an iron containing a certain proportion of carbon have long gone by. We have learned that the other elements always present in steel exert a decided influence on all the properties of the iron; but we are still far from understanding the real nature of the purest steel. While the inexperienced investigator may too readily imagine that he has struck at the root of the problem, Professor Arnold, an authority in this field, declared in a discourse delivered at Johannesburg, before the British Association, on August 31, that steel was probably the most complex substance extant, and that he had to confess, after research extending over a quarter of a century, that the more he learned about steel the less he knew of its ultimate nature.

Considering the vast progress that we have made in testing materials and the triumphant steel structures which engineers have erected, this statement may sound unnecessarily pessimistic. The careful designer allows an ample factor of safety, and the stability and strength of the bold buildings and bridges and huge ships which have been constructed in the age of steel demonstrates that the engineer must, to a certain extent, understand his chief building material. Scientists, Professor Arnold grants, have perfected the art of steel-making to such a degree that first-class material will, perhaps, not fail in more than one case out

* "Engineering," September 8, 1905.

of ten thousand. But failures do occur, and their mysterious character proves both that we do not comprehend the real nature of steel and that our methods of testing are faulty. The first fact will not be questioned; whenever the ultimate nature is approached, we have to confess our ignorance. But that our methods of testing on whose perfection so much ingenuity and money have been spent, should seriously be deficient, will not universally be conceded.

Homogeneity is the great aim which most metallurgists have in view. Professor Arnold, as will be seen later, thinks that safety is to be found in want of symmetry, not in the visible structure, such as the microscope reveals, but in the molecular grouping, about which the microscope does not tell us anything. He regards steel as an igneous rock, more or less crystalline. To go much further in the definition would, first of all, require a real satisfactory answer to the question, What is crystalline matter? In Professor Arnold's opinion there is a certain analogy between granite and steel. The granite is built up of quartz, felspar and mica; the steel of the constituents ferrite, pearlite and cementite. In an unsaturated steel containing about 0.5 per cent of carbon, the microscope allows us to distinguish patches of iron; the saturated steel, with 0.9 per cent of carbon, looks more homogeneously speckled with pearlite; in the supersaturated steel the iron carbide or cementite is seen to form cell-walls, and the cementation proceeds from outside. When the rail fracture occurred which caused the St. Neot's accident some years ago, it was suggested that manganese monosulphide might be responsible, as the steel contained 0.09 per cent of sulphur. But this sulphur was found to be uniformly distributed through the rail section in small patches.

Micrographic testing is held in high esteem, and nobody wishes to derogate its importance. But it cannot always guide us. When the carbonist theory had been abandoned, great hopes were placed on the allotropic theory. The iron of the α range, up to a temperature of about 740° C., was assumed to be soft; in the β range the iron was alleged to be hard; in the γ range, flint hard. The transition ranges seemed to coincide with the critical temperatures, at which recalescence and change in magnetic properties are observed. Experimenting on an ingot of a very pure steel, however, Professor Arnold found that

the alleged mechanical influence of allotropy did not exist. The ingot was rolled down, and the test-pieces, quenched at various temperatures ranging up to 900° C., were etched in nitric acid. The critical points did not affect the mechanical strength. The increase in tenacity began 200 degrees below the critical point, and for the range 500° to 900° C., the tenacity increased proportionally to the quenching temperature. The tests concorded so well that the deviations from the curve did not in any case amount to more than 0.167 ton per square inch, and were in most instances much smaller.

After this theory had been withdrawn by Osmond in 1901, polymorphic changes in the iron were suggested. Osmond reduced ferrous chloride by hydrogen, and collected crystals of the reduced iron on porcelain disks inserted in the porcelain tube. The looked-for rhombic crystals were not found. All the crystals were cubes and octahedrons, internally symmetric, though interfering with one another as to their external geometry. There was no trace of rhombic crystallization, and the whole problem was practically brought back to the state in which Clifton Sorby, of Sheffield, left it in 1863.

In spite of all chemical, mechanical, thermal and micrographic testing, strange failures were reported from time to time. One of the most characteristic in Professor Arnold's experience concerns the following case: The boiler of a warship had been passed, but later two plates split right across in a line nearly through, not quite parallel to the seam. The chronology of these testing operations is the following: Hydraulic pressure of 228 pounds, 260 pounds and 305 pounds per square inch was applied on February 5, 8 and 19; on February 20 steam pressure of 60 pounds was tried; on February 21 the boiler burst under an hydraulic pressure of 270 pounds. On closer examination it resulted that cracks were also developing between the bolts. The boiler was very carefully taken to pieces, the rivets drilled out, and the plates — 1 inch thick and weighing $3\frac{1}{2}$ tons — were straightened. During this straightening one of the plates split right across into three pieces, the other into five pieces. Samples planed off from the fractures proved most excellent. (See " Engineering," page 164, *ante*.)

A microscopic comparison was then made by Professor Arnold between this boiler steel and a sample of the best steel

obtainable. The pearlite fragments in the boiler steel were more coarse and angular, the ferrite drawn out into long lines or ghosts; but there was nothing to account for the fracture, and the static tests gave no clew. Professor Arnold then designed a new testing machine on Woehler's lines. The test rod, of about 4 inches in length, is held by a die which grips a length of about $1\frac{1}{8}$ inch; the other 3 inches project, and a reciprocating plunger takes hold of the free end and deflects it by $\frac{3}{8}$ inch at each alternation. The standard machine of this type for bolts up to $4\frac{3}{4}$ inch in diameter applies about 650 alternations per minute, and a good steel should stand 300 alternations. The fracture ensues along the die line. Under these alternating stresses, the fracture starts on the skin, on one or on both sides, and proceeds to the middle, where a filament is left, which finally breaks by tension. When both sides give way at the same moment, the filament will occupy the mid-position; if one skin gives way before the other, the filament will be found nearer the other side, which was later attacked.

When mentioning these tests for the first time at the Cambridge meeting of the British Association last year, Professor Arnold expressed the opinion that the outside and inside parts of the plate varied in their resisting stresses. This opinion he now withdraws. The strength really varies all through the material. This is shown by tests conducted under different conditions, with rates of alternations of 169 or 266 per minute; sixteen test-pieces from the outside of the plate broke after an average of 900 alternations (the extremes being 1,292 and 390 alternations), and sixteen pieces from the inside after 839 alternations (the extremes being 230 and 1,177). In both cases the different test-pieces behaved very differently, therefore, and there was no reason to give the preference to the outside or the inside pieces. The best obtainable steel was submitted to similar tests; complete fracture ensued after about 1,375 (from 1,330 to 1,456) alternations at the rate of 168 alternations per minute, and after 878 (from 860 to 916) alternations at the 266 rate; this steel was therefore much more uniform. Heat treatment was tried on the burst boiler steel. The treatment comprised oil- and water-quenching and annealing at several temperatures, but the material was not improved. Test-pieces which had failed after alternations of 230 and 1,240 (the extreme cases)

were then polished just below the fracture line and microscopically examined; they showed the same appearance, and all these test-pieces stood the cold bending tests remarkably well.

Somewhat similar experience was gained with an old boiler whose end plate had cracked right across. In that case also the ordinary tests could not account for the accident. The new line of thought which had suggested itself to Professor Arnold was finally strengthened by another observation. A garden gate had been held by a bolt of wrought iron, driven through a stone pillar. The bolt was hammered out of the pillar, and the projecting end broke off at the fourth blow of the hammer. Microscopic examination revealed the existence of a crystal which had cleft parallel to a cubical face; as iron is opaque, the cleavage could not directly be shown in the ordinary way on a slide. But the cleavage forms a series of steps, and the light reflected from those faces marks the lines of cleavage. If such cleavage can take place, we can conceive why steel sometimes breaks more like glass than like a ductile metal. Cases of this kind have hitherto been explained as results of fatigue; but this is only a convenient term coined to mask our ignorance.

The tentative conclusions at which Professor Arnold has arrived in explanation of sudden strange fractures of engine, boiler and structural steels is, that after the gross crystallization, discernible by the highest microscopical powers, has been completed on cooling, there set in, from a series of centers, molecular movements tending to the production of perfect mineral cleavage. This cleavage cannot easily be detected by the microscope, as steel is absolutely opaque to transmitted light. To avoid the development of cleavage planes the molecular structure of the steel should be asymmetrical. That crystallization proceeds from a series of centers can be demonstrated in many substances, and the decomposition and disintegration will start from the same centers.

As regards testing, Professor Arnold would not rely too much on dynamic and alternating stress methods, by which engineers are now guided to a considerable extent. They might land the engineer out of the frying-pan into the fire, he was afraid, for they indicated that steel with a high elastic limit was less liable to fracture under alternating stresses than a metal with a lower limit. Researches which he had carried out at Sheffield,

at any rate, had convinced him that under severe alternating stresses steel with a high elastic limit was, as a rule, more liable to rupture than softer low-limit steel. Nor did Professor Arnold wish to alarm the engineering profession; for these mysterious fractures are, fortunately, very rare.

Whatever we may think about the best method of testing and about the relevancy of the cleavage hypothesis, nobody will doubt that continued conscientious and systematic study of the steel problems is urgently required. It is satisfactory to state that the metallurgical department of the University of Sheffield, which Prof. T. O. Arnold has been able to create, is at present probably the best equipped in the world, and that it enjoys the sympathetic support of manufacturers, who enable their students to join the evening classes, in which they receive the same instruction as the regular day students. Chemistry, physics, geology, mineralogy and micrography are compulsory subjects at Sheffield, and our readers will grant that in the light of these novel researches none of these subjects could be dispensed with. If Great Britain is to maintain or to regain her supremacy in armor-plate and ordnance manufacture, — certain indispensable processes are not of British origin, — such institutions should be provided with ample funds from official and private sources.

METALLOGRAPHY APPLIED TO FOUNDRY WORK *

PART IV

By ALBERT SAUVEUR

The Photomicrography of Prepared Samples of Cast Iron

IN the preceding installments of this article I have briefly described the manipulations necessary to prepare samples of cast iron for microscopical examination, as well as the needed apparatus. To conclude the technological part of my subject, I still have to outline the photography of the magnified images of the samples. The desirability of securing photomicrographs, and, therefore, permanent records, of the structures under examination need not be insisted upon. The various steps once mastered, the operation becomes, moreover, a simple and inexpensive one.

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* "The Foundry," October, 1905.

Apparatus. — The camera shown in Fig. 1 as well as in Fig. 6 of the last installment ("The Foundry," page 7, September,

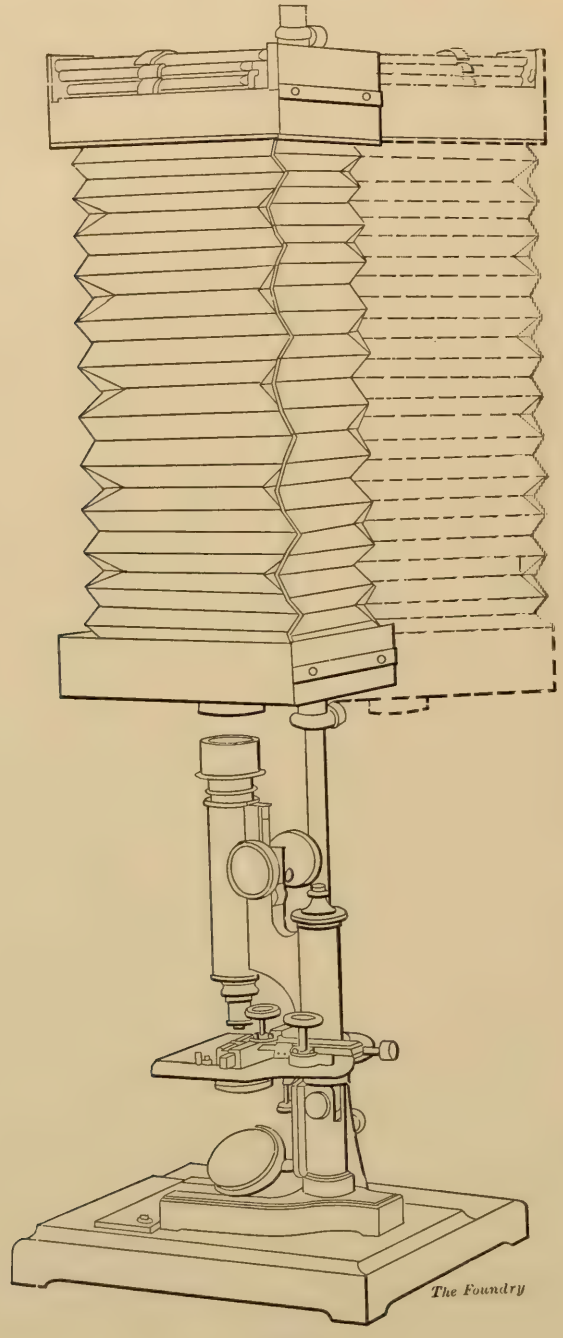


FIG. 1

1905), gives excellent satisfaction. It is used vertically and if the microscope be always kept in the same position on the base of the camera, all that is needed when it is desired to take a photo-

graph is to lower the bellows so that the light-proof connection it carries fits into a similar part attached to the tube of the microscope. Connection between the camera and the microscope is in this way quickly accomplished without disturbing in the least the specimen or the illuminating parts.

Manipulations. — The taking of a satisfactory photomicrograph may be considered as dependent upon the following factors: (1) The polishing and other preparation of the sample; (2) the illumination of the sample; (3) the focusing of the magnified image upon the screen of the camera; (4) the kind of photographic plate used; (5) the exposure of the plate; (6) the development of the plate and other dark-room manipulations and (7) the printing from the negative, toning, etc. Unless each of these factors is given the correct value a satisfactory photomicrograph is not to be expected.

The preparation of the samples has been dealt with elsewhere and I shall only add here that it is generally advisable to photograph a sample shortly after it has been etched, the structure being then generally more sharply defined and brighter. A slight rubbing of the polished surface over a piece of chamois leather just before placing it under the microscope also frequently brightens it and otherwise improves its appearance.

The other factors just indicated as influencing the quality of the photomicrograph will now be briefly considered in the order named.

Illumination of the Sample. — Any of the illuminating apparatus described in the last installment may be used for taking photomicrographs, but the arc lamp outfit is by far the most satisfactory. With a weaker source of light, such as a Welsbach lamp or an electric incandescent lamp, the exposure requires considerable time, even when using low-power objectives, while it becomes objectionably long when using high powers. With high-power objectives, moreover, the amount of light which reaches the screen, in case of a weak source of light, is relatively so small as to make a satisfactory focusing of the sample very difficult.

Whatever the source of light used, great care should be taken to secure as intense and uniform an illumination of the sample as possible through suitable manipulations of the lamp, condensing lenses, vertical illuminator, etc. The light-proof

attachment should then be inserted and the bellows of the camera lowered as shown in Fig. 1, when the next step will be to focus the image upon the screen of the camera.

Focusing. — This is probably the most delicate operation connected with the taking of photomicrographs, and one which cannot be slighted. Three conditions are essential to success: (1) The center of the image should occupy the center of the screen; (2) the image should be evenly lighted; and (3) it should be accurately focused so as to secure maximum sharpness and clearness. The image can generally be properly centered by a slight rotation of the disk of the vertical illuminator as well as by the rotation of the illuminator itself, while following with the eye the motion of the image upon the screen.

The absolute necessity of securing a perfectly even illumination of all parts of the image will be obvious and this is to be brought about through suitable manipulations of the parts affecting the path of the beam of light, that is the lamp itself, the condensing lenses and the vertical illuminator.

The image should be focused as accurately as possible by gently turning the fine adjustment screw of the microscope, and with the assistance of a focusing cloth. A focusing glass may be used with great advantage for this operation and is of special importance when photographing with high-power objectives. It consists of a magnifying glass suitably mounted, but an ordinary eye-piece may be used with nearly as good results. This lens or eye-piece should be placed on the plain glass circle which occupies the center of the screen of the camera, and the image carefully focused while being viewed through this lens. By this means we magnify the image and are, therefore, able to focus it more sharply in its finest details. Considerable light, however, is lost, and the object will generally appear but dimly lighted. The rule to follow while using a focusing glass is to secure the clearest possible image while working the fine adjustment tentatively in both directions, bearing in mind that at its best, the image may appear blurred and dimly lighted.

When an electric arc lamp is used it is advisable to considerably reduce the light after focusing, by a partial closing of the iris diaphragm. In doing this we, of course, increase the exposure time, but as is well known a sharper negative is generally secured.

Kind of Plates. — While any good photographic plate may be used, I prefer the so-called "process" plate made by Carbutt, Seeds' "contrast" plates or other similar plates. They are generally relatively slow but they yield sharper negatives, having great contrast.

Exposure of the Photographic Plate. — After the image of the sample has been properly focused the sensitive plate should be introduced and exposed, with the ordinary precautions, for a suitable length of time. The time of exposure will vary according to (1) the kind of plate used, (2) the illumination and (3) the nature and color of the sample. The illumination will in turn depend upon (1) the source of light, (2) the adjustment of the illuminating parts and (3) the magnifying power and some other properties of the eye piece and objective.

It is not possible to give positive information regarding the needed time of exposure. Each student must experiment a little before being able to judge accurately. As a guide, and when using the relatively slow plates mentioned above, and a Welsbach lamp, it may be said that with low-power objectives, yielding a magnification say of 100 diameters, the exposure will generally vary between five and twenty minutes, according to the character of the sample and the care with which the illumination has been adjusted. Higher powers required considerably longer time. With a more intense source of light such as that furnished by a 50 candle-power incandescent lamp, and especially with that of an electric arc lamp, the time of exposure is, of course, much shorter, in the latter case varying from a fraction of a second to five or six seconds under the least favorable conditions.

Development of the Photographic Plate. — While any good developing formula may be used, my preference is for the old-fashioned potassium oxalate-ferrous sulphate developer, using six parts of a saturated solution of oxalate of potassium to one part of a saturated solution of protosulphate of iron. To retard the oxidation of the iron it is advisable to add a few crystals of tartaric or citric acid to the iron solution. The solutions should be mixed only as needed. The ordinary intensifiers and restrainers may be used in the usual way if the plate shows signs of having been under or over exposed, but I should advise the beginner to make another negative in case of decided ill-timed exposure, as probably the shortest road to success.

Printing. — Whether a printing out or a developing paper should be used for taking prints from the negatives is largely a matter of individual preference. Personally I prefer the former,

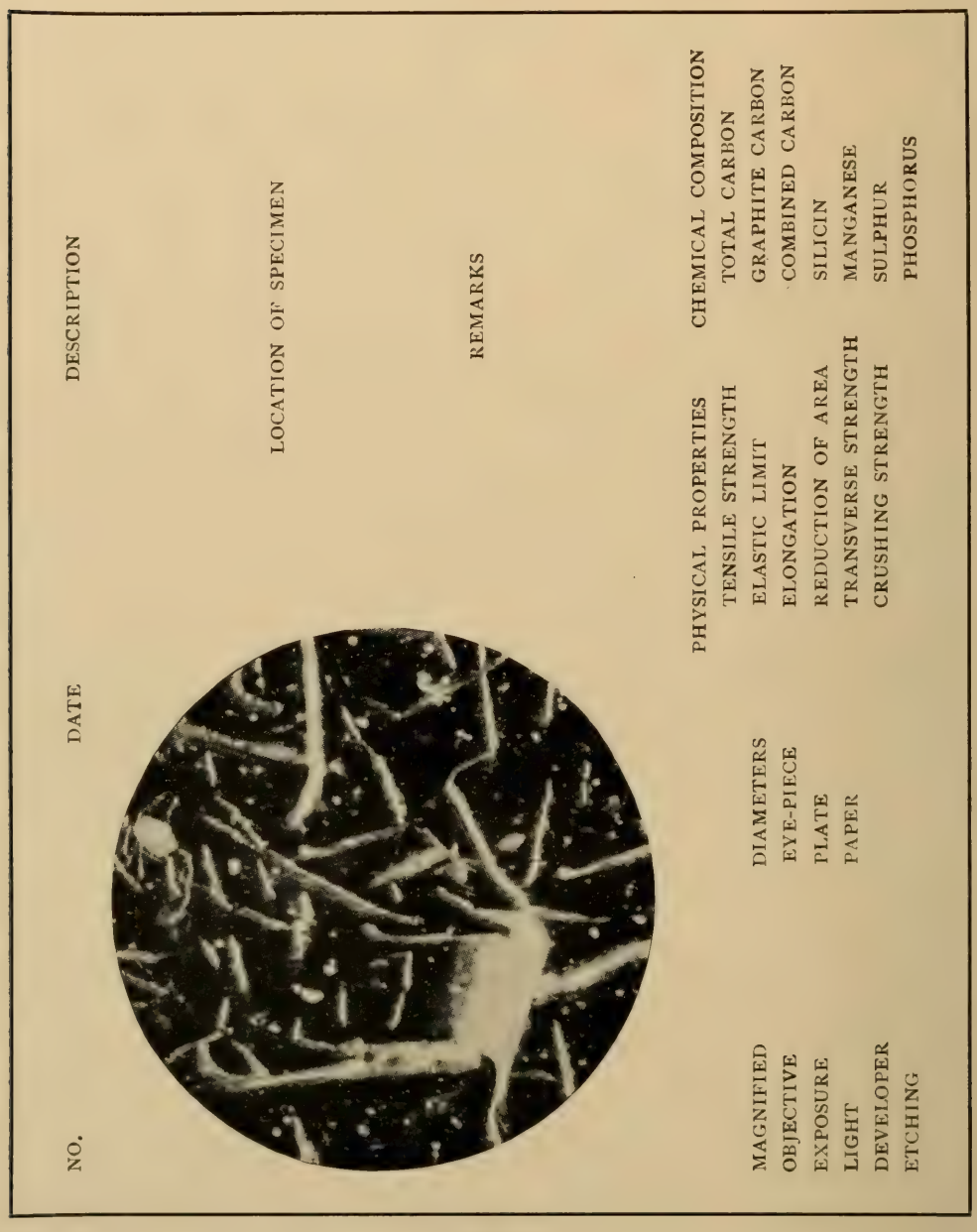


FIG. 2

but I am well aware that many favor some developing paper. Drying on ferrotype plates affords a quick means of finishing silver prints and giving them a satisfactory luster. It is recommended to cut the prints to circles some $2\frac{1}{4}$ inches in diameter

by means of a margin trimmer and suitable form, as this will give them a very neat appearance.

Mounting. — The prints should be pasted on special cardboard mounts, such as is shown in Fig. 2, with descriptive matter and blank spaces to be filled. I also find it very useful to mount every print on index card, including the same printed and descriptive matter as that of Fig. 2, stamping upon each sample the same number as that of the index card, and by keeping the samples in a suitable cabinet, any desired sample together with its photomicrograph and accompanying information may at a moment's notice be taken from the collection. Finally, it is also advisable to print the same information and to mount a print on the envelopes or negative preservers in which the plates are kept. Such system greatly facilitates the work and adds to its effectiveness.

CRYSTALLINE AND AMORPHOUS STATES OF METALS*

WHEN, a few years ago, Mr. G. T. Beilby published the first account of his researches upon the hard and soft states of metals, his work excited more curiosity perhaps than real interest. It appeared strange that metals should yield to the gentle pressure of the fingers, and "flow" and transform their surface layer into a vitreous film. The great part played by surface tension in liquids did not at once suggest the importance of these modified surface layers. Yet it should be clear that if on the surface of solids which have undergone certain mechanical treatment there is something like the elastic skin which is apparently stretched over the surface of a liquid, that fact would strongly influence our tensile strength tests. This side of the question has, within the last few months, been touched upon by Mr. Beilby, in a communication which he has brought before the Royal Society; and the presidential address which he delivered to the Chemical Section of the British Association at the Johannesburg meeting, on August 29, reviews the whole problem from a broad theoretical standpoint. Osmond and others have taken up these researches, which in many

* "Engineering," September 22, 1905.

respects deserve the attention of the engineer. We have already drawn our readers' attention to them.

Gold films which are being polished behave exactly like a liquid under the influence of surface tension. The molecules tend to heap up in minute mounds or flattened droplets. Sometimes the mounds are so shallow as to become visible under illumination by an intense oblique beam of light, and such films may be not more than 5 or 10 micro-millimeters in thickness. They would contain only from 10 to 20 million molecules in their thickness. Moderately thin gold films become translucent at a temperature of 400° to 500° C., and show by transmitted light the forms resulting from surface tension. The astounding malleability and durability of gold is not unlimited. The finest films of gold and platinum are utilized as electrical resistances; and when carelessly beaten, gold-foil develops cracks round its edges. That the original softness can be restored to the gold by beating has long been known to the artificers. In iron and steel, heat annealing is, as a rule, associated with the growth of crystalline grains; under over-strain these grains become deformed by slips occurring along cleavage plains, as Ewing and Rosenhain have shown. Similar observations have been made on other metals; but it is not clear why malleability and ductility should reach their limit at a point when the crystalline grains are, to all appearance, only slightly deformed. The polished surface film retains no trace of crystalline structure, and seems to have passed through a liquid condition. It may be assumed that the conditions which prevail at the outer surface might also occur at the inner surfaces where movement had taken place, so that every slip of one crystalline lamella over another would cause a thin film of the metal to pass through the liquid phase into the non-crystalline condition. Beaten pure gold-foil reaches its hardest and least plastic condition only when all trace of crystalline structure has disppeared. This state is limited to the surface layers; for in the interior the hardened substance produced by the flowing under the hammer appears to encase and to protect the crystalline units, after they have become broken down to a certain size. It can be shown by careful etching that underneath the vitreous surface of the gold there remains a layer of minute granules, and beneath these again the distorted fragments of lamellæ and grains are met with,

embedded in a vitreous and granular matrix. When the metal is annealed by heating, the crystalline structure is again observed on etching.

Mr. Beilby's researches prove that the property of passing from the crystalline to the amorphous phase by mechanical flow, and from the amorphous to the crystalline phase by heat at a definite transition temperature, is general, and possessed by all crystalline solids which do not decompose at, or below, their transition temperature. He further argues that this change ranks with the great changes which result in the three generally distinguished states of aggregation — the solid, liquid and gaseous. All these changes mark alterations in the molecular activity at certain temperatures and other conditions. On grounds which require further elucidation he assumes that the amorphous-crystalline change is different from the allotropic changes which the chemist ascribes to certain elements and compounds. We know that sulphur occurs both in the rhombic and in the prismatic modifications, which differ somewhat in physical and chemical properties, and which are both stable within certain temperature ranges. Both modifications are crystalline, and as the perfect amorphous state is characterized by the absence of all crystalline structure, there is a difference between the phenomena. The crystal is a living unit; it can grow, and may be described as being in a state of dynamical rather than in a static equilibrium. Below a certain temperature, however, the crystal, to all appearance, becomes a mere pseudo-morph, with no power of active growth. But those powers are not extinct; they are only in abeyance, and ready to be called forth by the energizing influence of heat. At extremely low temperatures all chemical affinity seems to become latent.

Hadfield has recently extended to iron and its alloys Dewar's early experiments on the behavior of metals at the temperatures of liquid oxygen and hydrogen. He conducted observations at ordinary temperatures and at —182° C. The tenacity and hardness of the metal and alloys were invariably enhanced at the extremely low temperature, and they returned to exactly their former value when the ordinary temperature was reattained. The tensile strength of a pure iron increased from 23 tons at +18° C. to 52 tons at —182° C.; that of gold, from 15 to 22.4 tons; that of copper, from 19.5 to 26.4 tons. The increase

can hardly be ascribed to a closer approximation of the molecules, for the actual expansion coefficient of most metals below 0° C. is extremely small; nor can it be due to permanent changes of molecular aggregation, for Hadfield obtained a perfectly smooth and regular cooling curve for iron between +18° and —182° C. We must rather suppose that the abstraction of heat produces a reduction in the repulsive force of molecular vibration, such that the primary cohesive force can assert itself more and more.

These researches prove, so far as they go, that the relation between temperature and tenacity continues unchanged down to the lowest attainable temperature. Both Dewar and Hadfield tested their metals in the annealed or crystalline condition. Assisted by his son, Mr. H. N. Beilby, B.Sc., Mr. G. T. Beilby has attacked this problem from the standpoint of his phase theory of the hard and soft state of metals. When tenacity is measured by the tension required to tear asunder a bar or rod, it is assumed that the tensile stress is uniformly distributed over the whole surface at which rupture ensues; but this is clearly not justified. It is impossible to experiment on a single chain of molecules, and only in a perfectly rigid body could all the pairs of molecules be pulled apart, as they would be in a single chain of molecules. If we depart from perfect rigidity, the molecules under strain will move over each other, and the rupture will become to a certain extent like that of a highly viscous body (molten glass, *e. g.*), in which the molecules evade any direct pull by slipping over each other. In the ductile metals the crystalline phase is mechanically unstable, while the amorphous phase only becomes unstable at a definite temperature. That the amorphous phase of ductile metals should, on Mr. Beilby's views, be the hard state, and the crystalline the soft, seems to contradict the accepted ideas; for hardness and brittleness are generally associated with the crystalline state.

But Mr. Beilby regards the softest metals as those which pass most readily into the crystalline conditions, and which are in their softest stage when in this condition. The softness, in his opinion, is due to the readiness with which the crystals can be broken down into the amorphous state. The crystalline state, in other words, marks the mechanical instability, the amorphous state the thermal instability. Annealed wires in the crystalline,

or C, state stretch when they are stressed beyond the yield-point; hardened wires, practically in the amorphous, or A, state, do not stretch, but break without extension when their limit of tenacity is exceeded. The homogeneous C phase of ductile metals has no true breaking point; it yields and stretches when stressed beyond the elastic limit, and in doing so passes partly into the A phase, rupture finally occurring at the breaking point of the mixed structure. The tenacity of this mixed structure approaches that of the homogeneous A phase, but does not quite reach it. A wire which has been hardened simply by stretching differs from a wire hardened by hammering or drawing, and in order to obtain the nearest approach to the homogeneous A phase the C phase is broken down by wire-drawing in Mr. Beilby's recent experiments.

Wires about .5 mm. in thickness were used. After drawing the wires through a series of die-plates to four or five times their original length, all crystalline structure seems to have disappeared; yet the wire consists of minute granules of the C phase embedded in a matrix of the A phase; the structure is still mixed. Further drawing at the same temperature alters the structure only slightly; there appears to exist a certain mechanical equilibrium between the phases for each temperature. But when the drawing is continued at lower temperatures, the A phase is more completely attained. The drawing was sometimes repeated until fifteen times the original length had been reached. Wire-drawing can be overdone, especially at ordinary temperatures — that is to say, the tenacity may decrease. It is evidently advisable to draw wires at the lowest possible temperature when high tenacity is aimed at, and that temperature may be even below —182° C. Gold gave the highest tenacity when stretched to three and a half times its original length.

The experiments so far concern metals of great purity — that is, gold of 99.97 per cent, silver of 100 per cent, and copper of a conductivity of more than 100, yet not quite so pure as the two other metals. In making the tenacity tests, a water load was applied, so that the speed of loading could be controlled, and the wire was submerged with its grips, the extension being measured after taking the specimen out of the liquid air. The wires broken at ordinary temperature (15° C.) showed no general stretching. There was a slight extension of .5 or 1 per cent,

entirely due to a sharp reduction of the diameter at the point of rupture. In liquid air all the wires stretched from 11 to 12 per cent over their whole length between the grips; this was ascertained by careful measurements. The appearance of the fractured ends revealed some interesting points. The ends of the broken copper wires showed the cupped formation, due evidently to the lower tenacity of the central core, which may be ascribed to the presence of gas bubbles which the drawing operation had transformed into long tubes. Some silver wires also indicated cupped formation; in this case, however, the gas bubbles did not appear to have been evolved before the moment of fracture. The gold wires were practically free from sponginess, and the fractures were almost perfectly viscous. The tenacity tests yielded the following figures: Gold wires at +15 and —182° C. gave a strength of 15.6 and 22.4 tons per square inch; silver wires, 25.7 and 34.4 tons; copper wires, 28.4 and 36 tons at the same temperatures. The figures are not to be regarded as final, and it looks as if Dewar and Hadfield had also been working with partly hard-drawn and not with annealed gold. In the crystalline state the molecules exert their mutual attractions along directed axes. Further experiments with metals in the amorphous state may throw light on the question whether, and to what extent, the crystalline state depends upon a dynamic equilibrium between the forces of cohesion and repulsion, or whether a directed cohesion exists fully developed in the molecules at the absolute zero.

This is a most interesting suggestion. Primitive or blind cohesion holds undisputed sway at absolute zero temperature, while with rising temperature the repulsion due to the molecular vibration becomes more and more strong. The interplay between the two forces continues through the three states of aggregation, until cohesion can be ignored in the gaseous state. It is on account of this latter fact — the absence of cohesion in gases — that the gas laws are so simple, and that we base most of our conclusions regarding the molecular constitution of matter on the study of gases. So far all this is, of course, not novel. But Mr. Beilby reduces the whole problem to a question of heat energy. The mathematician will have to be consulted. But Mr. Beilby is no doubt right in pointing out that these problems are more likely to be elucidated by a study of the successive

stages between the absolute zero and the vaporizing temperature than of the upper ranges where the gaseous state alone prevails. The most instructive field for investigation may be that of middle temperatures where the opposing forces are more nearly equal.

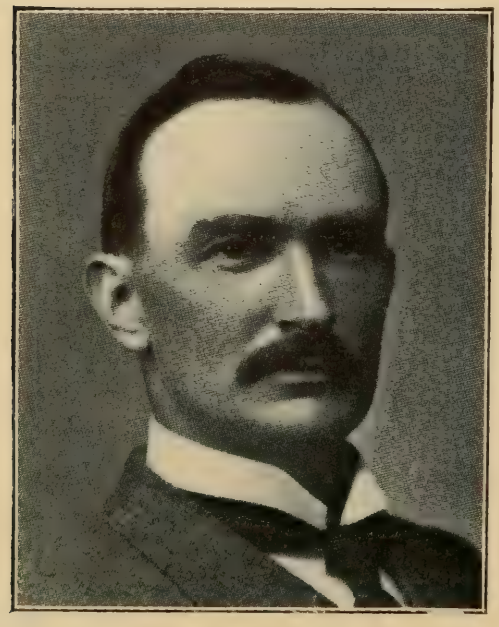
The sizes of the ultimate solid particles have been estimated by optical means. Faraday ascribed the various colors exhibited by gold under different conditions to the size of its particles and their state of aggregation. Ruby glass and ruby solutions, he proved, are not true solutions, nor molecular diffusions of gold, but emulsions containing the gold in aggregates of sufficient size to produce a sensible reflection of light. Zsigmondy and Siedentopf came to a different conclusion a few years ago. They succeeded in making these ultra-microscopic particles visible in the microscope as diffraction disks; they counted the numbers of the disks and calculated their size from the intensity of the reflected light, and as they observed particles ranging from 4 to 791 millionths of a millimeter, they did not believe in any relation between size and color of the particles. J. Maxwell Garnett has lately demonstrated that the color of metallic films and glasses depends not only upon the size of the metallic particles, but also on the proportion of the volume they occupy in the medium in which they are diffused.

This is not easy to understand; but Mr. Beilby's observations, which agree with those of Garnett, suggest an explanation of much that was puzzling. He thinks that the actual microscopically-visible particles and the larger particles which can be measured in films, solutions or suspensions, do not in any way represent the ultimate units of structure which are required by Garnett, but that they are aggregates of smaller units built up in more or less open formation. This argument leads us back to the coarse visible structure with which considerations of the hard and soft states are concerned.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

SEGREGATION in Steel Ingots. B. Talbot. Paper read at the September, 1905, meeting of the Iron and Steel Institute. 9,000 w. — The author reports the results of an investigation conducted to ascertain the effect of aluminum in decreasing segregation in steel ingots. Both acid and basic open-hearth steels were examined, the weights of the ingots varying between $1\frac{1}{2}$ and $3\frac{1}{2}$ ton.



As a rule, the results show that in the case of ingots to which no aluminum has been added, excessive segregation down the central line of the ingot occurs from about 6 inches from the top to about half-way down the ingot, that sulphur is the element which tends to segregate most, phosphorus next, followed by carbon, and finally manganese, the segregation of which latter element is so slight as to be almost negligible. No silicon determinations were made, as the amount of this element present was extremely small.

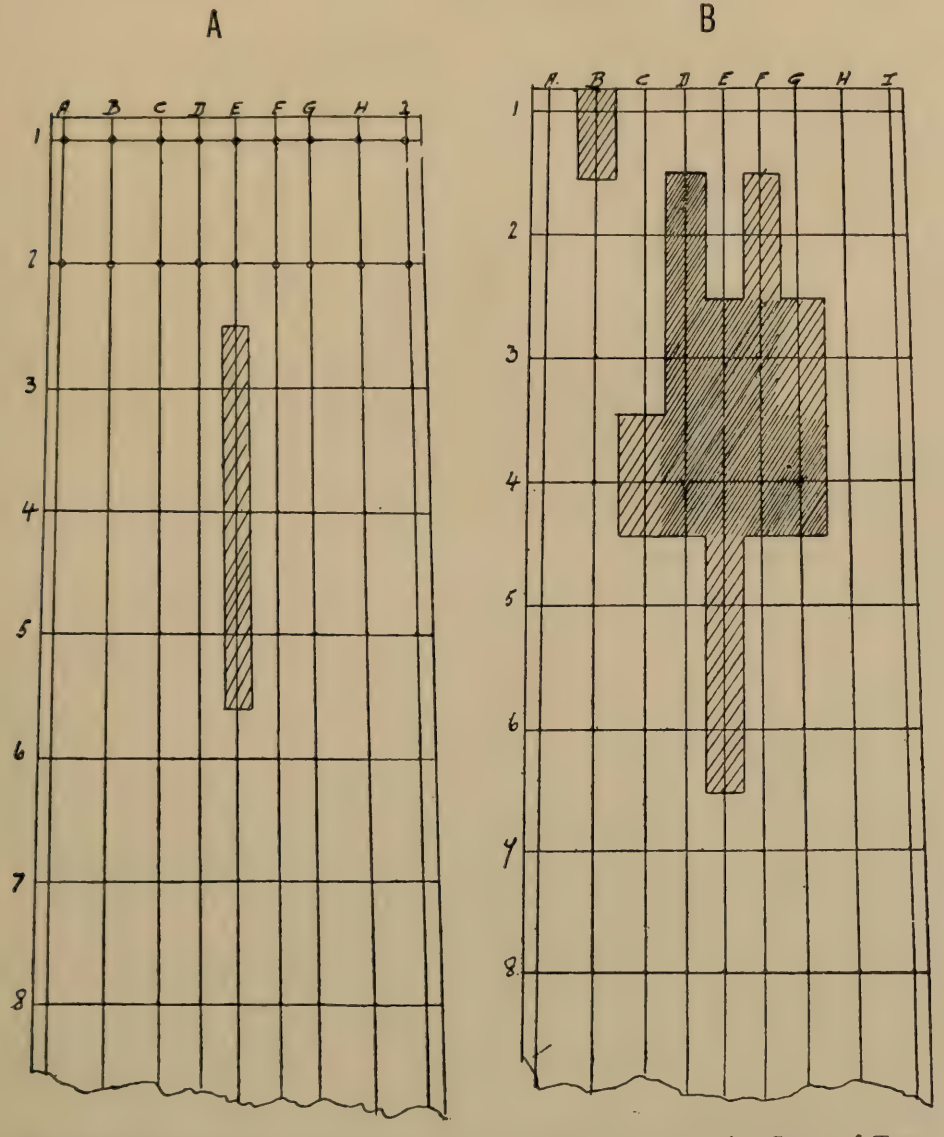
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* Note. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

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The accompanying illustration shows the marked effect of aluminum in decreasing the segregation of S in an acid open-hearth steel ingot.

An examination of the results shows clearly that by the use of aluminum a billet of a much more regular composition



Showing Segregation of Sulphur in the Same Heat in the Case of Two Ingots. A, with Aluminum; B, without Aluminum. Parts shaded show the areas in which the sulphur has increased 25 per cent over ladle test. The darker shading shows approximately areas with over 75 per cent increase of sulphur.

is obtained. This is especially important in the case of carbon, especially if this steel had without aluminum been intended for

rail purposes, as the surface of the rail would probably have shown considerable irregularities in the carbon percentage, with a consequent want of uniformity in its wearing properties.

In cases in which the carbon has segregated to the center, it is obvious that corresponding areas will be found at the sides in which the carbon is less than the mean, through the carbon having migrated to the center to a greater or less extent.

As in cases in which aluminum has been added the segregation is lessened, the distribution of the carbon over the surface of the ingot is found to be much more even, and to approach more nearly to the composition given by the ladle test.

The author's experience on the addition of aluminum in the ingot mold during casting has always been that the aluminum appears to make the metal set quicker. This, he is aware, is against the view usually held by metallurgists. Thus, in Mr. Harbord's recently published book on steel, it is stated: "The addition of very small amounts of metallic aluminum to such metal" (*i.e.*, metal containing dissolved oxides) "is found to cause a marked increase in the fluidity of the molten metal, to stop the evolution of gas and to allow of the production of sound ingots without blowholes." Mr. Harbord, however, does not seem entirely satisfied with this view, as on the same page, in referring to Mr. Hadfield's classic work on aluminum steel, he tells us that, according to that investigator, it is doubtful whether aluminum increases the fluidity of properly made steel. This latter view falls in with the facts observed by the author, under whose directions aluminum has been added regularly to many thousands of casts.

Not only does the addition of a little aluminum to the metal as it is run into the ingot have a marked effect in setting the surface, but it also, in the author's experience, tends, when added above a certain quantity, to form cavities in the upper part of the ingot, so that the amount added has to be strictly regulated. The setting effect on the top of the ingot is so marked that at the works with which the author was connected after it had become the custom to add aluminum regularly, the ingots were never sanded over or stoppered down, as no such treatment was necessary, either with acid or basic open-hearth steel. With mild steel also it was found that the molds could be stripped sooner when aluminum had been added.

It was also observed that when the same quantity of aluminum, viz., some 3 to 4 ounces per ton of steel, was added to the metal as it ran into the ladle, its effect was not so pronounced as when added in the ingot mold as the ingot was being teemed.

There appears, therefore, to be somewhat of a contradiction in the facts observed, some authorities telling us that aluminum in small quantities increases the fluidity of the metal; others, with whom the author joins, contending that the reverse is the case. Theoretically, one would undoubtedly expect some increase in temperature, owing to the reaction between the dissolved oxides in the metal and the aluminum, an action akin to the well-known thermite process.

If an increased temperature is obtained, with the consequent increased fluidity, this would cause the steel to take longer to solidify, and would consequently tend to increase the segregation, provided that the aluminum has no special action of its own on the metal, whereas the numerous analyses made by the author prove that there is a considerable diminution in the amount of segregation. As the metal appears to set quicker, and as, consequently, segregation would be expected to be less, due to this quicker setting, the analyses seem to agree with this view. The author's usual practice was to add about 3 to 4 ounces of aluminum per ton of steel in the ingot, but this was never added until the ingot mold was approximately two thirds full. Assuming the aluminum to be all concentrated in this top third of the ingot, it would then only be at the rate of about 12 ounces per ton, or about .033 per cent aluminum.

In the author's opinion it would be well worth while for other investigators, interested in the manufacture of higher carbon steel, such as for rail, tire and similar purposes, to follow up these results, with a view to proving whether a more uniform and regular steel is not thereby obtained, a result well worth the few pence per ton the aluminum would cost. Perhaps the chief result to be looked for would be the decreased amount of crop end that it would be necessary to cut off from the top of the ingot due to the greater solidity of the top and the lessened amount of segregation in this top part of the ingot. This alone would undoubtedly pay for the cost of the alumi-

num added, without considering the more regular quality of the finished product as a whole. **No. 419.**

I. The Use of Vanadium in Metallurgy, and II. Steel used for Motor Car Construction in France. Léon Guillet. Paper read at the September, 1905, meeting of the Iron and Steel Institute. 25,000 w.; illustrated. — The author gives the results of an extensive research into the properties of vanadium steels. He concludes as follows:

" It may be affirmed that in all the cases studied up to the present vanadium considerably improves the mechanical properties of metallurgical products. Its effect may be characterized as follows:

" 1. On normal steels it produces a very distinct increase in the tensile strength and elastic limit, and has no influence, or an insignificant one only, on elongation and contraction, and upon resistance to shock. It slightly increases the hardness.

" 2. On quenched steels vanadium considerably increases the tensile strength and elastic limit; it acts in this way with almost as great an effort as carbon, yet, notwithstanding this, it does not increase the brittleness.

" The influence of vanadium in metallurgy is thus, in my opinion, of considerable importance. It is undoubtedly the element which, together with carbon, acts with the greatest intensity in the way of improving alloys of iron — that is to say, in very small percentages.

" It is to be specially noted, however, that alloys of iron, carbon and vanadium are more sensitive to heat treatment and mechanical handling than ordinary steels, but this does not appear to be any longer the case in more complex alloys, particularly in nickel-vanadium steels.

" It remains to consider the influence of the addition of vanadium upon the cost per cent of the vanadium contained. The cost of production of ferro-vanadium is such as to readily allow of its addition, and if, at the moment of writing, the price of ferro-vanadium is still high (about £1 per pound of vanadium contained), this must be attributed to the scanty demand, which is altogether inadequate, and consequently entails expenses of manufacture which are spread over but a very small output, thus considerably increasing the price.

This state of affairs will disappear when the use of vanadium becomes more widespread. It may be concluded that the employment of vanadium in the manufacture of special steels is distinctly indicated, particularly in the manufacture of quaternary alloys such as iron-nickel-carbon-vanadium.

"It is probable that vanadium will give highly interesting results with copper and its alloys, but no systematic study relating to this has yet been carried out."

The author also considers the special steels being used for motor-car construction in France, which he classifies as follows:

"(1) Steels with low percentages of carbon and nickel (pearlitic steels), which are used for parts which require cementing and quenching, *i. e.*, shafts, gears which engage directly, etc.

"(2) Steels with medium percentages of carbon and low percentages of nickel, used, after quenching and reheating, for a large number of parts, shafts, gearing, pinions, etc.

"(3) Steels low in carbon and with high percentages of nickel, used for valves.

"(4) Chromium steels, with high carbon and low chromium percentages, used for bearings.

"(5) Silicon steels, used for springs and for gearing.

"(6) Nickel-chromium steels, with low percentages of nickel and of chromium, employed for numerous parts requiring resistance to shock, and a certain degree of hardness.

"(7) A new steel known as NY, the composition of which has not been published." **No. 420.**

Methods for the Prevention of Piping in Steel Ingots. (Die Verfahren zur Verhütung der Lunkerbildung in Stahlblocken.) R. M. Daelen. "Stahl und Eisen," August 15, 1905. 1,700 w., illustrated. — The author describes the fluid compression and other methods of preventing piping. **No. 421. D.**

A Study of the Causes of Blow Holes in a Steel Ingot. (Untersuchung über den Ursprung eines Blasenraumes in einem Flusseisenblocke.) Dr. H. Wedding. "Stahl und Eisen," July 15, 1905. 2,400 w., illustrated. **No. 422. D.**

The Reversible and Irreversible Transformations of Nickel Steel. L. Dumas. Paper read at the September, 1905, meeting of the Iron and Steel Institute. 13,000 w.; illustrated. — The author describes an extensive investigation of the reversible and irreversible transformations of nickel steel, from which he draws the following conclusions:



Two facts stand out above all the others contained in this paper: 1. Nickel manganese and carbon introduced into a steel determine alike the appearance of the same phenomenon, irreversible transformation, which is more intense the higher the proportions in which they are present.

2. It is not sufficient that they should be present in the steel; it is necessary besides, in order that they should exert the full effects that they are capable of, that they should be in solution, a state which is often, as regards carbon, impossible of attainment without the aid of chromium.

Solution. — If it be sought to ascertain what constitutes the state of solution, it will be found that nickel steels present the most perfect examples known. Metallography has never been able to detect in these steels the slightest segregation; no physical treatment appears capable of destroying their homogeneity, and yet they are not chemical compounds of definite composition. It would seem that chromium nickel steels realize, in the most perfect manner known, what is termed solid solution.

Saline solutions are subjected to internal stresses, called osmotic pressure; it would not be surprising, therefore, that an internal stress of growing intensity should be occasioned in the steels in proportion as nickel is added; it reveals itself by an internal "working," resembling that of steels which have undergone the irreversible transformation.

Allotropic Transformations of Iron. — Why is it that the internal stresses disappear so suddenly when the added elements reach a certain proportion? In order to answer this question it is necessary to bring into consideration a very remarkable property of iron; that of being able to undergo allotropic modifications.

We may say, therefore, in accordance with the terminology adopted by Mr. Osmond, that the state of internal tension disappears when the point Ar3, below which iron ceases to exist in the γ state, is lowered, by means of a proportion of nickel, or of other elements, to below the ordinary temperature. Now when the iron is free from all alloys, this point is situated at 850° C. It is the dissolved elements which have retarded the transformation; this may well be admitted, inasmuch as the point Ar3 is seen to fall gradually in proportion as the additions increase.

So long as the iron is in the γ state in the steel, no internal stresses arise. A stress, even when severe, may be the result of an external force. This is a fact which I have shown to be related to the other fact that the volume increases when the transformation manifests itself by an internal working. The appearance of the internal stresses is one of the characteristic manifestations of β iron produced by the transformation, which is also shown by the microscope, by the martensitic structure, and in the mechanical tests by a considerable increase in the hardness and brittleness. Nickel steels with high proportions of β iron are those which contain large amounts of foreign elements, and have undergone the irreversible transformation. The transformation also causes a portion of the iron to pass into the α state; it is this portion alone which is magnetic. It is at its maximum proportion in unworked steels which contain the minimum proportions of foreign elements.

These considerations will permit of the whole of the complex facts related in the foregoing account being still more succinctly stated.

The properties of nickel steel are the same as those of iron, modified, and even exaggerated, by the influence of the elements it holds in solution, yet at the same time perfectly recognizable, particularly that of undergoing allotropic modifications.

The movement of the molecules is hampered by the presence of nickel or of other elements. Mr. Hadfield has recently given a peculiarly striking example of this by submitting to mechanical tests in liquid air Swedish irons of great purity and nickel steels. At the temperature of liquid air the Swedish iron became extremely brittle, but it recovered all its toughness on returning to the ordinary temperature. At the same temperature the nickel steel had lost very little of its tenacity, because the nickel impeded the movement of the molecules, and prevented them from forming crystals.

The highly remarkable properties of those nickel steels which have not undergone the irreversible transformation have occupied the principal place in the foregoing paper. Because of their high percentages of nickel they are, unfortunately, so costly to produce that they are beyond the range of current industrial application. It would seem, therefore, at first sight, that a minute study of their properties was almost useless from a practical point of view.

The direct utility of these investigations is, perhaps, greater than might be apparent at first sight, but I will confine myself to remarking that they possess an indirect utility of prime importance, in showing the nature of the operation involved in adding nickel to steel.

Two effects are produced: the homogeneity is increased, and a form of what is otherwise known as " working " results; the condition of mutual solution is improved, and β iron is produced. With very low percentages the first effect predominates, the crystallization of the iron is impeded and the brittleness lessened. The action of the nickel is analogous to that of a quenching carried out at 1000 degrees, which, as is known, greatly diminishes the brittleness of soft steels. It may be remarked, in passing, that it is much more practicable to introduce nickel than to quench when large masses are concerned.

The second effect, intensification of the proportion of β iron, which counterbalances the first named, must not, however, be lost sight of. The improvement in the state of reciprocal solution impedes crystallization, but occasions osmotic pressure, *i. e.*, both removes and confers brittleness. This explains why additions of nickel, which, up to about 2 per cent, are devoid of danger, begin to become so above this percentage. The steel

early assumes the characteristics of a highly worked metal, corresponding to a quenched carbon steel. Above 8 or 10 per cent of nickel the steel is difficult of employment, that is, until the proportion reaches that which induces the transition of the iron to the γ state.

Will the application of steels of this category always remain somewhat rare? It may be permitted to doubt it, and the success of Mr. Hadfield's non-magnetic manganese steel justifies this doubt. In the meanwhile there is nothing to hinder the extended use of steels with low percentages of nickel; they are admirably adapted in all cases where it is important to diminish brittleness or to reduce weight. **No. 423.**



The Nature of Troostite. Carl Benedicks. Paper presented at the September, 1905, meeting of the Iron and Steel Institute. 5,000 w., illustrated. — The author recalls the original definitions of Osmond regarding the nature of troostite and opposes Boynton's suggestion that troostite might be β iron. "It is quite natural to assume," the author writes, "that troostite is that part of martensite in which cementite has just begun to form (incipient pearlite formation), but that owing to the rapidity of the cooling, the separate particles of cementite do not attain to such a size that they can be distinguished microscopically."

Boynton's theory must fall or stand by the presence or absence of troostite in hyper-eutectoid steel, and the author contends that Boynton avoids the difficulty by calling this troostite "sorbite." "The facts," he writes, "are in entire accord with the hypothesis that troostite is a pearlite with ultra-microscopically small particles of cementite." The author, moreover, is inclined to consider troostite as resulting from a transformation *in situ* of martensite, although Osmond did not

wish to insist upon this. The following conclusions represent the author's views.

In conformity with this the author has already formulated in the work referred to the difference that can appropriately be made between troostite and sorbite, and will venture to repeat it here:

" If a piece of martensite or austenite has already begun to undergo transformation which ultimately results in pearlite, we have troostite.

" If the martensite has not succeeded in completely resolving itself into pearlite, we have sorbite.

" Troostite is the first, sorbite the last, stage of transformation between martensite and pearlite."

In the author's opinion one might set up this practical criterion: If the bulk is composed of martensite ($\pm$ austenite), but certain parts become dark on etching, these are called troostite; if the bulk is composed of pearlite, but certain parts become dark on etching, these are called sorbite. But this question is and remains one of names.

In conformity with the experimental works of Osmond, Le Chatelier, Heyn, Boynton and Kourbatoff and with his own observations, the author is led to the following conclusions:

1. Everything we know at present points to the fact that Osmond has quite correctly defined troostite as an intermediate form between martensite and pearlite.

2. Between troostite and pearlite there is a continuous transition, and one is naturally led to the conclusion that troostite is a pearlite with ultra-microscopically small particles of cementite (containing also more or less hardening carbon). This hypothesis is the simplest and the most natural one to accept until it be shown that it is contrary to truth.

This is in keeping with the fact of the extreme ease with which troostite is affected by reagents, with its varying hardness, which lies between that of martensite and that of pearlite, and with the fact that troostite, from a steel rich in carbon, yields cementite when slightly heated, as Kourbatoff has shown.

3. In all probability troostite is formed by a transformation *in situ* of martensite, which implies that the carbon it contains must be the same as in the martensite from which it originates.

Boynton's assumption that troostite is pure β iron is without experimental or theoretical support. Similarly Kourbatoff's

suggested theory, that troostite is a solution of elementary carbon in iron, is untenable.

4. Troostite is formed from martensite by the appropriate lessening of the intensity of the hardening, especially in places that are in contact with ferrite or cementite; this is in perfect conformity to theoretic requirements.

5. As far as we can judge, troostite offers in the domain of alloys an interesting analogy to the colloid solutions.

Since the above was written, Rogers, in a paper on troostite, has taken into consideration the different arguments in favor of troostite containing carbon, contrary to Boynton's hypothesis. He says, however, that he fails to see why troostite should be β iron rather than γ. **No. 424.**

The Influence of Nickel and Carbon on Iron. G. B. Waterhouse. Paper read at the September, 1905, meeting of the Iron and Steel Institute. 12,000 w., illustrated. — The author describes the results of an investigation conducted in the Metallurgical Laboratory of the School of Mines of Columbia University and consisting in the study of the properties of a series of steel of constant nickel content (about 3.80%) with varying carbon percentages, while the other elements were kept as low and constant as possible. The following conclusions are drawn from the results obtained:

1. Nickel decidedly raises the tenacity without materially lowering the ductility. The elastic ratio in pure nickel-carbon steels is only slightly greater than that of carbon steels.

2. Annealing has a marked influence; it lowers the tenacity without greatly raising the ductility.

3. The constituents of steels with low-percentage nickel in the unquenched state are: ferrite, pearlite, cementite and graphitic carbon.

4. The pearlite of these steels shows a great readiness to segregate into its constituents: ferrite and cementite.

5. In this condition the cementite has the formula $Fe(Ni)_3C$.

6. The eutectoid ratio in these steels appears to lie at about .70 per cent carbon, but in the rolled steels no free cementite shows until the carbon reaches about 1.00 per cent.

7. Nickel lowers the transformation points $Ar_{3.2}$ and Ar_1 about 20 degrees for every 1 per cent of nickel.

8. The cementite of these steels is very liable to precipitate its carbon as "temper graphite." **No. 425.**

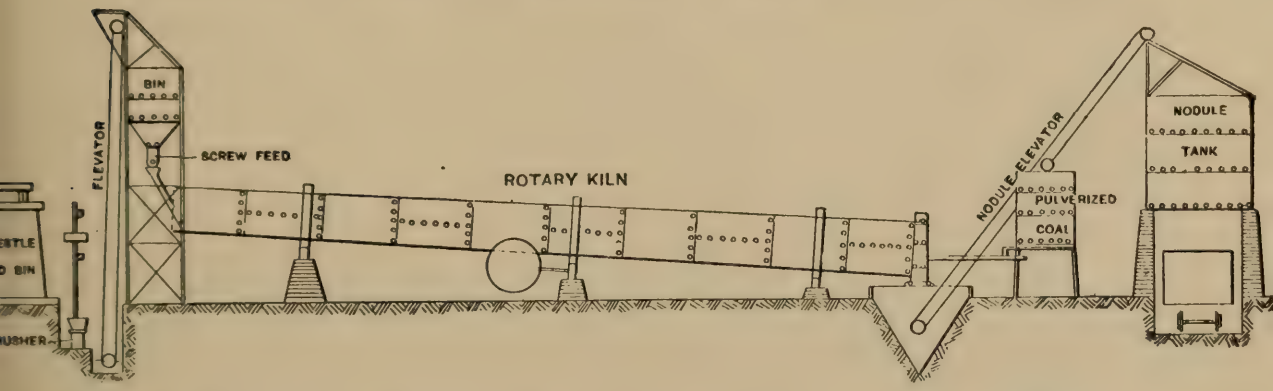
Process for Converting Fine Iron Ores into Nodules. "Iron Age," September 7, 1905. 2,500 w., illustrated. — Description of a plant of the National Metallurgic Company at Newark Bay, N. J., for the production of ore nodules from fine ores. The process is being applied chiefly to the residue from the treatment of iron pyrites for the production of sulphuric acid and which is known as "blue billy." The present process differs from previous ones in that it employs tar (though patent claims are made also on other adhesive substances and carbohydrate compounds) which has an affinity for and forms volatile compounds with such impurities as sulphur and arsenic. Along with these impurities it is gradually volatilized, the iron oxides being converted into nodules of any desired size, free from moisture. The adhesive substance is not used to bind the particles of ore together permanently, but its function is to bind them initially, and in the progress of the ore through the rotary kiln (see illustration) used for the production of nodules aid in fusion, the final product being permanently coherent nodules containing substantially no fixed foreign compounds.

It is found that the size of the nodules can be regulated by varying the quantity and quality of the binder, the degree of heat and the rapidity of movement of the ore through the kiln. In practice under Mr. King's process the addition of 1 per cent of pitch to 99 per cent of an ore analyzing 67 per cent metallic iron and 1 per cent silica produces nodules about the size of a goose egg, a size adapted to open-hearth work, while $\frac{1}{2}$ per cent of pitch added to $99\frac{1}{2}$ per cent of the same ore produces nodules the size of a partridge egg, the size best adapted to blast-furnace practice.

The National Metallurgic Company has erected what it terms an ore purifying and nodulizing plant, with a capacity of 200 tons in twenty-four hours. The object has been to construct as far as possible an automatic or continuously operating plant.

The ore, or pyritic cinder, is received by railroad or boat, is stored under a trestle and in bins, and from the bins or from the stock piles is mechanically conveyed to a rotary kiln for treatment.

Referring to the elevation of the cinder treating plant, it will be seen that the cars drop the ore into a series of bins under the trestle. These bins discharge either directly into a crusher or, if the ore is in such a condition of fineness as not to require crushing, into a storage tank located above the feed end of the rotary kiln. From this storage tank the material is conveyed by screw conveyor to a feed pipe which projects down and into the end of the kiln. At the same time that the fine ore is delivered from the storage tank tar is dropped into it as it reaches the end of the screw conveyor farthest from the tank. There is thus a thorough mixing prior to the admission of the ore into the kiln. The tar tank surrounds the exhaust chimney of the kiln, and thus the tar is kept warm and fluid. Held in masses by the preliminary binding of the tar the ore moves along



Elevation of Ore Storage and Feed Bin, Rotary Kiln and Nodule Conveying and Storage Plant

in the kiln under a horizontally rotary motion, encountering different degrees of heat, the temperature increasing toward the farther end of the kiln. Before merging from the kiln the nodules are agglomerated or permanently semifused; progressing still further they are discharged through a hood and conveyed by elevators to the nodule tank for final disposition.

The fusion of the ore is accomplished by the injection of powdered coal into the discharge end of the kiln, and an important feature of the plant is the coal dryer and its accessories. The dryer is located adjacent to the bins under the trestle, and the coal is carried by conveyors to the dryer bins and through the latter automatically. The dryer deviates from the usual form in that the heated gases and waste products of combustion after passing on the outside of the dryer return to the front, and thence

pass directly over the coal dryer to discharge through the chimney stack.

From the dryer the coal is discharged into a bin from which it is conveyed to a Griffith mill. The latter runs at 1,800 revolutions and produces a ground coal of which 90 per cent will pass a 100-mesh sieve. A screw conveyor brings it to the ground coal tank, thence it is propelled by screw conveyor and dropped into a blow pipe, a fan blowing it into the hood at the discharge end of the rotary kiln. The point of fusion in the kiln depends on the amount of air pressure, the fusion zone being either drawn toward the hood or thrust further back toward the feed end, as required by the desired size of ore nodules.

The field of the process described above is broader than the operations thus far carried on. Its use for the conversion of flue dust into nodules is under consideration, the flue-dust problem having assumed no small proportions under the increasing use of Mesabi ores. But a more important field is capable of development by the installation of ore-nodulizing plants at Lake Superior iron mines, whose ores are of unusual fineness. The removal of moisture from Lake Superior ores previous to their shipment from the mine has been agitated for a number of years. It has been considered a commercial proposition to dry these ores at the mine, but prosperity has pushed any serious operation in this direction into the future. A process that removes moisture and at the same time converts the ore into such form that practically no flue dust is produced is naturally important to Lake Superior mining interests, as well as to furnacemen using Lake ores, and it may be stated that some steps are in contemplation for such an application of the process above described. **No. 426. A.**

Note on the Occurrence of Capper, Cobalt and Nickel in American Pig Iron. E. D. Campbell. Paper presented at the September, 1905, meeting of the Iron and Steel Institute. 1,800 w. — The author reports the results of the analysis of many samples of American pig iron for nickel cobalt and nickel, and he finds that two points of interest are brought out by a study of these results.

First, the fact that two samples, made from ores from the Lake Superior district, contain no copper, cobalt or nickel,

although the Gogebic Range is comparatively near the great copper-producing district of Lake Superior. The second point relates to samples which are the only ones containing any considerable amount of cobalt or nickel, and both of these irons have gained a reputation for their valuable properties for car-wheel castings. The author has no information in regard to the influence of small amounts of cobalt or nickel on the properties of cast iron, and the occurrence of these elements in these two irons mentioned may be a mere coincidence, but it is at least suggestive. **No. 427.**

A Manipulator for Steel Bars. Douglas Upton. Paper read at the September, 1905, meeting of the Iron and Steel Institute. 1,000 w., illustrated. — The author describes a manipulator for steel bars which consists of a series of three machines, the first of which consists of two pairs of movable heads which are installed at each side of the roughing and finishing rolls. These heads can move in either direction parallel to the rolls. They are preferably actuated by hydraulic cylinders, and they place the piece in position for entering any required pass. These heads, moreover, are fitted with levers for turning the piece up for edging purposes; not only will they turn the piece up, but without actually gripping it, will maintain it in that position until it enters the rolls. **No. 428.**

The Keep Sectional Cupola. "The Iron Age," August 31, 1905. 1,400 w., illustrated. — The article describes a recent cupola furnace designed by W. J. Keep and built by the Northern Engineering Works, Detroit, Mich. The furnace is composed of four sections easily handled and assembled. **No. 429. A.**

Car Wheel Forging. James H. Baker. "The Iron Age," September 7, 1905. 2,200 w., illustrated. — The author describes the forging of car wheels as conducted by the Solid Steel Tool and Forge Company, Pittsburg, Pa. **No. 430. A.**

A Process for the Prevention of Piping in Large Steel Ingots. (Verfahren zur Verhütung der Lunkerbildung in Schweren Rohstahlblocken.) F. O. Beikirch. "Stahl und Eisen," August 1, 1905. 1,800 w., illustrated. — The process consists in the use

of sinking heads which are afterwards removed, together with the piped portion. **No. 431. D.**

The Department of Iron and Steel Metallurgy at the University of Sheffield. J. A. Arnold. Paper read at the September, 1905, meeting of the Iron and Steel Institute. 2,800 w., illustrated. **No. 432.**

Cleaning Blast-Furnace Gas. Axel Sahlin. "Cassier's Magazine," October, 1905. 5,500 w., illustrated.—**No. 433. B.**

METALLURGICAL NOTES AND COMMENTS

Robert Forrester Mushet

Robert Forrester Mushet (see frontispiece) was the son of David Mushet, the discoverer of the Scotch Black Band iron stone, and like his father an enthusiastic metallurgist. His most important achievements are the invention of self-hardening steel and the addition of spiegeleisen to the refined metal at the end of the Bessemer blow. In a recent issue of "The Ironmonger," the advent of self-hardening steel is briefly related in the following words:

"Like other important inventions, that of self-hardening tool steel was an accidental discovery, due to the observation of the effect of a draught of air upon some tools which had been left near the bottom of a door. It was then proved that if tools were reheated to a full scaling or almost yellow heat their quality was improved. Mr. Mushet himself, while experimenting for another purpose, found that one of his trial bars had the property of becoming hard, after being heated, without the hitherto necessary water-quenching, and that this property was due to the presence of tungsten. In 1871, the manufacture of Mushet steel was taken up by S. Osborn & Co., of the Clyde Steelworks, Sheffield, and its superior cutting qualities soon gained it a world wide reputation. Subsequently the majority of the Sheffield steelmakers added a self-hardening tool steel to their products. Mushet steel was undoubtedly a forerunner of the modern high-speed steel."

The part taken by Mushet in the final success of Bessemer's pneumatic process is too well known to need repetition in these columns. While it would be unwarranted to affirm that were it not for his coöperation the Bessemer process would have failed, it may at least be said that his assistance greatly hastened the success of the process. It is probable that the following remarks of William Menelaus, then president of the Iron and Steel Institute, on the occasion of the presentation to Mushet of the Bessemer Gold Medal in 1876, correctly express the opinion of metallurgists at that time and that the same opinion still prevails

to-day. "It is needless to inquire very particularly what success attended Mr. Mushet's attempts to improve old processes, because they were all overshadowed by the beautiful invention of the spiegeleisen process, as applied to his friend Mr. Bessemer's great invention, and it was upon that ground that the council resolved to pay Mr. Mushet the compliment that they then did. He thought they would agree with him that the application of spiegeleisen, in the way it was done to Mr. Bessemer's invention, was one of the most elegant, as it certainly was one of the most useful, inventions ever made in the whole history of metallurgy, and he thought it would be conceded also that for that alone, if for nothing else, Mr. Mushet well deserved the compliment they were about to pay him. It was an invention which was worthy of being associated with the great invention of Mr. Bessemer. The two inventions would go down together; in fact, the one was the complement of the other, and he thought he was right in saying that no man in that room could be better pleased than his friend, Mr. Bessemer, that the council had resolved to pay that compliment to Mr. Mushet. He thought it was a fit and seemly thing that the medal instituted by Mr. Bessemer should compliment the man who had made what he thought was really a brilliant invention. It had made the invention of Mr. Bessemer perfect, and probably would be used in England as long as Bessemer metal was made."

It is well known that Mr. Bessemer never recognized the validity of Mushet's patents, and this is forcibly stated in his recent autobiography, from which the following remarks are quoted:

"For a period of more than two and a half years (1857–60) after the date of Mr. Mushet's three manganese patents, I had no intimation of any kind that either I, or my licensees, were infringing any of these patents. But about three or four months prior to the date when a further £100 stamp was required to be impressed on them, to prevent their forfeiture, I received a letter from a Mr. Clare, of Birmingham, calling himself Mr. Mushet's agent for the sale of steel, and requesting an interview with me and my partner at my office in London on the following morning. On his arrival, he explained the object of his visit; it was simply to say that Mr. Mushet was prepared to grant me a license to use his manganese patents for a nominal sum; he merely wanted his rights acknowledged. I then told Mr. Clare that we considered

that Mr. Mushet had acquired no rights under either of his three manganese patents, and that we entirely repudiated them. I also told him that we were anxious to meet any claims legally preferred; that we were prepared, on any day to be mutually arranged, to receive Mr. Mushet and his solicitors and witnesses at the Sheffield works; that we would allow them to see the crude iron converted and recarburized with spiegeleisen, made into an ingot, and forged into a bar, and that I would personally take that bar to one of my customers and sell it to him in their presence; and then the prosecution of our firm for infringement would be a very simple matter. This offer resulted in Mr. Clare's retirement from my office, and after that interview we never heard from him, or from Mr. Mushet, on the subject."

Mr. Bessemer also writes that he paid Mushet over £7,000 in annual allowances of £300 and other payments. The reason for these disbursements Mr. Bessemer also states in his autobiography.

"There was a strong desire on my part to make him my debtor rather than the reverse, and the payment had other advantages; the press at that time was violently attacking my patent, and there was the chance that if any of my licensees were thus induced to resist my claims, all the rest might follow the example, and these large monthly payments might cease for such a period as the contest in the law courts might last. The annoyance, if nothing else, would have been very great, and I had neither time nor patience to wage a paper war from year's end to year's end with unscrupulous writers. In the hope that an allowance to Mr. Mushet might have the effect of restraining these attacks on me, I offered to pay him £300 a year, aiming at abating an intolerable nuisance which I had no other means of preventing. While we were paying over £3,000 per annum in the form of income tax, the £300 was but a small additional tax on my resources, so I allowed it to drag on until Mr. Mushet's decease, in 1891, having thus paid him over £7,000. So, naturally, ends this part of this history of my invention, as far as Mr. Mushet is concerned."

Electric Smelting.*— With the development of electro-metallurgical processes in other parts of the world the possibility

* "Engineering Magazine," October, 1905.

of applying the methods of electric smelting of iron and refining of steel to the industry in Great Britain is attracting attention. In a paper recently presented before the Manchester section of the Society of Chemical Industry, Mr. R. S. Hutton shows that the position of England in this respect is by no means so discouraging as some would believe. Incredulity in this respect is largely based upon the fact of the limited water power available, but it must not be forgotten that the power cost is but one element, and not always the controlling one.

"Many leading electrical engineers have published minute data as to the cost of power generation, but only for electric lighting, traction and motor purposes. These cases, however, are so entirely different in character from those we are concerned with that no definite conclusions can be drawn from this evidence. The average power station is fortunate to get a 15 per cent load factor, and overjoyed with 30 per cent; whereas, in nearly all electro-chemical works, the manufacture is continued night and day throughout the year, and the load factor may be taken as 100 per cent. If one may judge from the evidence of those few who have had actual experience in electro-chemical industries using steam power, a figure of £6 to £8 for the horse-power year is quite attainable under such conditions. With producer gas this may probably already be brought down to £4 in Great Britain. For the sake of comparison, it may be pointed out that although in some few places in the Alps and Norway a figure as low as 17*s.* per horse-power year has been attained, water power is very seldom to be obtained so cheaply. At Niagara the price of supply to large consumers varies from £3 11*s.* to £4 3*s.* and at Rheinfelden reaches £6 for the horse-power year.

"So far as blast-furnace gas is concerned, no very sure data are available for similar industries. The supply of cheap gas power is likely to prove so beneficial to Great Britain in the application of the industries we are about to consider that it is earnestly to be hoped that those who are concerned in the construction of large gas engines will be led to take an interest in these developments. With their coöperation the number of remunerative electro-chemical industries may be very largely increased in England."

There does not appear to be any immediate probability of the introduction of electric methods for the reduction of iron

from the ore, but Mr. Hutton gives some interesting points about the relations of electro-thermic processes to the present smelting methods.

" The application of the electric furnace to the metallurgy of iron, with the exception of some few small-scale experiments, which are more of historical than technical interest, may be said to be largely founded on the experience gained in the manufacture of calcium carbide. Carbide furnaces have been and are being largely used for the production of rich ferro-alloys such as ferro-chromium and ferro-silicon, and in this way electro-metallurgy has already been of considerable service to the steel industry. As the production of calcium carbide became less and less remunerative, and as the demands of the market for these ferro-alloys became satisfied, definite attempts were made to tackle the problem of the direct reduction of iron ores.

" It might seem to be rather a hopeless task which the electro-metallurgist has thus set himself; for direct competition with the blast furnace is obviously out of the question so far as our own and probably all other present iron-producing countries are concerned. On the other hand, there are certain advantages which can be gained by electric heating, and although the electric reduction of iron ores is at the moment unremunerative, we may expect to hear more of it in the future, when the general development of electric furnace construction is more advanced.

" Every ton of pig iron produced in the blast furnace requires very nearly one ton of coke for its production. Of this amount only one third is necessary for the chemical reduction of the ore, the balance being employed in producing and maintaining the requisite temperature. This two thirds of the fuel supply can be replaced by electric heating.

" In actual practice, so far, only the simple case of reducing the ore and allowing the carbon monoxide to pass away unused has been tried. Various methods have, however, been proposed by Héroult, Harmet and others for utilizing the total heat of combustion of carbon. Under these conditions it should be possible to reduce iron ore with a much smaller power expenditure. The perfecting of methods along these lines is a matter for the future."

In considering the question of the electric production of steel the matter should be examined on its own merits, and not

in connection with the ordinary processes. So far as the matter of power is concerned the results of the investigations of the Canadian commission show the power expenditure per 1,000 kilograms of steel to range between 500 and 1,000 kilowatt hours, the lowest expenditure being that of the Kjellin induction furnace, which was charged with molten pig and cold scrap, while the largest power expenditure occurred when the charge was cold.

More important than the power consumption, however, is the quality of the steel produced by the employment of electric refining processes.

" In the first place, there seems to be good evidence to show that steel, equal in quality to the best Sheffield crucible steels, can be produced in the electric furnace. This can be accomplished either in such a furnace as that of Kjellin which, in its present form, is used almost entirely for melting up carefully-chosen raw materials, and does not rely on any considerable refining of the material. On the other hand, with the Héroult furnace such a product can be obtained starting with almost any grade of raw material; this process relying essentially on its capability of rapidly and completely refining pig iron or ordinary scrap steel. The economical advantages of using a cheap grade of raw material for producing high quality crucible steel will doubtless tell in favor of such a method. It is largely to such possibilities of refining and to the relatively high cost of fuel per ton of product for the manufacture of crucible steel that the electrical processes owe their advantages.

" From the investigations of the Canadian commission it appears that in nearly all cases the whole operation of melting and refining the raw material has been effected by electric heating. In Great Britain, where coal is cheap, it is almost certain that much of this heating could be more economically carried out by the combustion of fuel. In the case where molten iron or low-grade steel can be run into the electric furnace, it will be seen that the power expenditure required for refining it and bringing up its quality to that of a crucible steel is indeed very low. Along such lines as these, the electric furnace may be expected to find still wider application than to the manufacture of high-grade crucible steel."

The Metallurgical Congress at Liége.* — We have given elsewhere in this issue a fully illustrated account of the engineering features of the international exposition now being held in Liége, Belgium, and, following the custom usual with such exhibitions there have been held various technical congresses and scientific gatherings, concerning which reports are now beginning to appear. In recent issues of " Le Génie Civil " is given an excellent summary of the proceedings of the Congress of Metallurgy from the pen of the well-known metallurgist, M. Léon Guillet, himself an active contributor to the work of the congress.

The congress, which was attended by about 1,600 delegates, including some of the most eminent metallurgists and engineers from Belgium, France, Germany, England, etc., had its work divided into five departments, treating of groups of metallurgical work. The first section considered problems relating to large operations, such as the manufacture of pig iron and of steel, the production of power from furnace gases, the utilization of slag, etc. The work of the second section related to special methods and progresses, such as the manufacture of alloy steels, electro-metallurgical processes and the like. In the third section there was discussed the treatment of iron and steel products, such as the heat treatment of steel, and the effects of rolling and mechanical working of the metal. The fourth section was devoted to the study of metallography, while the fifth took up processes having an indirect relation to metallurgy, such as the brazing and welding of metals, etc.

It is impracticable, within the space here available, to comment upon all the papers submitted before the congress, but some of the more important communications may be noticed. Thus M. E. Bian, the director of the iron works at Eich, in Luxemburg, described the method which he has found satisfactory for purifying the gases from blast furnaces, rendering them suitable for use in gas engines. This apparatus consists of a cylindrical chamber filled half full of water, and containing a shaft carrying a number of disks of metallic netting, these disks being kept in constant rotation. The gas, passing through these, parts with its dust and other matter in suspension, and the disks are continually washing themselves in the water, this latter being constantly renewed.

* " The Engineering Magazine," October, 1905.

An interesting matter in connection with the work of the first section was the discussion of the Gayley dry-air blast for blast furnaces. The correctness of the theory of the process is fully borne out by the facts developed in the discussion. Thus a table prepared by M. Divary, of the Creusot works, shows that the fuel consumption of a furnace under his observation bore a close relation to the hygrometric condition of the atmosphere. Taking the fuel consumption in January as a base, there being 6.3 grams of water per cubic meter of air, and the daily production of the furnace being 90 metric tons, there appeared in July, when a cubic meter of air contained 13.6 grams of water, an excess consumption of 133 kilograms of coke, while the output of the furnace fell to 70 tons per day. The results for other months showed a close correspondence as to the variation in coke consumption and in iron production, with the variation in the proportion of moisture in the air, these figures agreeing closely with those observed by Mr. Gayley at Pittsburg. It is intended to introduce the refrigerating process of drying the air at the Creusot works, as well as in other establishments in Belgium and Germany.

In discussing the theory of the dry-air blast, M. Le Chatelier showed the injurious action of moisture in the air in connection with the presence of sulphur in the iron. By the use of air which is free from moisture any sulphur which is present is converted into sulphurous anhydride, which is entirely absorbed by the limestone in the upper zones of the furnace, where iron itself has not yet reached the spongy condition in which it can take up the gas. The sulphur thus passes off entirely in the slag, a condition which does not occur in the presence of moisture.

The much disputed subject of slag cements came up for discussion at the congress, and Professor Wedding, of Berlin, expressed himself of opinion that slag Portland cement, made by recalcining and grinding briquettes made of granulated slag and lime, does not differ chemically from ordinary Portland cement, while the results of mechanical tests are entirely comparable.

Passing to the work of the second section, this included discussions upon special alloy steels, M. Guillet himself furnishing a classification of these products, according to the manner in which the added metal combines with the iron and with the

carbon. M. Guillet gave several diagrams showing the influence of the different constituents upon the properties of resistance to rupture, to shock, to elongation and upon hardness, these enabling a general idea of the effects of the various constituents to be determined and compared. Referring to the ternary steels, these including those containing iron, carbon and one other constituent, M. Guillet says that the nickel and the manganese steels may sometimes take the place of carbon steels; that the polyhedric steels should have an important industrial future if the price can be brought sufficiently low; that the tungsten and molybdenum steels have shown themselves of great value for high-speed tools; and that there is apparently no practical use for the graphite steels.

So far as the interesting subject of electrometallurgy is concerned, the principal point brought out at the congress was the fact that the well-known projectile works of Jacob Holtzer, at Unieux, has put into service a steel-refining furnace of 1,000 kilowatts, capable of producing 7,000 to 8,000 kilograms of steel at a charge.

In connection with the works of the section devoted to processes of treatment of iron and steel, mention may be made of the researches of Hadfield upon the effects of low temperatures upon alloy steels, already noticed in these columns; and of the paper of M. Creplet, upon the application of electric power to the driving of rolling mills.

Of especial importance was the paper of M. Le Chatelier, in the fourth section, upon the subject of metals and alloys by the methods of metallography. M. Le Chatelier discusses the methods of polishing the surface of the metal to avoid surface hardening, describing the preparation of the emery and alumina for working the surface, and the use of various solutions for etching the polished metal. The use of picric acid, originating in the laboratory of M. Le Chatelier, is now well known, but a later method in the use of heated saline solutions containing an oxidizing substance. By using a 25 per cent solution of caustic soda with 2 per cent of picric acid, heated to 100° C., the cementite is attacked, without any action being produced upon the other constituents.

In the production of the microphotographs M. Le Chatelier prefers the Nernst lamp to the mercury arc, and the details of

his microscopic apparatus have been worked out with great care. After all the care which can be taken, much depends upon the skill and judgment of the operator, and in this, as in other departments of investigation, it is impossible to be assured of uniform results.

In the auxiliary metallurgical subjects attention was directed at the congress to the use of the oxy-hydrogen and the oxy-acetylene blow-pipes for the welding of metals. There appears to be no doubt that satisfactory welds may be made with either apparatus, and the decision from the industrial viewpoint depends mainly upon the cost. The use of electrolytically produced gases is of interest so far as the oxy-hydrogen apparatus is concerned, but the advantage in point of cheapness appears to lie with the oxy-acetylene blowpipe.

The Cause of Brittleness in Steel.* — Among the various physical and mechanical properties of the numerous iron alloys grouped under the generic name of steel, that of brittleness, or as the French call it, fragility, has caused much perplexity. Two products, apparently the same in chemical composition and in visual constitution, will be found to be quite different in behavior under shock, one being tough and resistant, while the other breaks without warning. Attempts to devise physical tests to discover the causes of this action, or at least to separate the good material from the bad, have met with but partial success, although various forms of drop tests are now realized to be of much value in commercial investigations. Examinations of portions of structures which have failed in service have not given any very clear indications as to the causes of sudden breakages, and it has been felt that some better knowledge of the origin of the property of brittleness would have to be discovered before the practical side of the subject could be pursued further to any material advantage.

We now have a paper in the "Révue de Métallurgie," by M. Hjalmar Braune, giving a theory of brittleness based upon his investigations of the past six years, this paper being of a preliminary nature and to be followed by a more detailed account of the experimental researches upon which it is based.

Briefly, M. Braune maintains that brittleness is due to the

* "Engineering Magazine," October, 1905.

presence of combined nitrogen taken up by the iron during various stages of its manufacture. The nitrogen appears to be combined entirely with the iron itself, with the ferrite, forming what may be called a nitrogenized iron; the carbides such as the cementite being entirely free from any nitrogen. This nitride of iron appears as a solid in solution in the ferrite, and acts to lower its point of fusion and at the same time diminishes its capacity for dissolving carbides of iron. In this way the nitrogen exerts a marked influence upon the quality of the metal, whether it be a soft iron or a hard steel or cast iron.

These statements may be proved by a few simple experiments. A test piece of iron or steel of the highest quality is placed in an atmosphere of ammonia, and raised to a temperature of 800° C. for a period more or less prolonged. These pieces are then annealed in sand, to permit the combined nitrogen to become homogeneously distributed through the metal. The behavior of pieces thus treated, when tested, shows very clearly the influence of the nitrogen upon the resistance. When the content of nitrogen reaches 0.07 to 0.08 per cent the elongation rapidly diminishes, and becomes discontinuous, while for higher percentages of nitrogen the ductility of the metal practically disappears. In some instances the surfaces of the test pieces became covered with fine cracks, these effects appearing in pieces in which the annealing had not been sufficiently prolonged, so that the greater portion of the nitrogen remained near the surface.

The effect of the presence of the nitrogen may also be observed by making a metallographical examination of the test specimens. The original untreated metal showed a constitution composed of large cells of uniform surface. Under the presence of nitrogen the appearance of these cells becomes modified, parallel striæ of corrosion appearing, while the dimensions of the cells continually diminish. Some of the cells retain their original appearance, while others become completely granulated. Some are partly modified and it is possible to perceive the manner in which the passage of the degradation from one cell to another is resisted. When the content of nitrogen approaches 0.07 to 0.08 per cent the cells become very small, scarcely one tenth of their original size, and at the same time the cement which fills the separating spaces between them increases in thickness. When

this structure is developed the metal has become wholly brittle. If the nitrogen content attains 0.2 per cent the cellular structure wholly disappears and appears only a series of dark lines, giving a more or less characteristic pearlitic aspect.

The cellular structure appears to bear a distinct relation to the ductility of soft iron. The larger the cells, the more ductile the metal. The cement which forms between the cells contains the impurities in the metal. A content of nitrogen as high as 0.07 per cent very rarely appears in commercial products, but in very soft irons, particularly in the products of Lancashire, a very much lower percentage of nitrogen will suffice to render the metal hard and brittle.

The influence of nitrogen upon hard steels is also very distinct. M. Braune discusses the behavior of a steel containing 1.15 per cent of carbon, when given increasing quantities of nitrogen by heating in an atmosphere of ammonia. At first there is a slight increase in resistance and reduction in elongation; then, suddenly, between 0.03 and 0.035 per cent of nitrogen, the elongation disappears entirely; the metal becomes completely brittle. For a steel containing 0.50 per cent of carbon the critical proportion of nitrogen corresponding to the disappearance of ductility is 0.040 to 0.045 per cent, while for a steel of 0.02 carbon this effect is produced by 0.050 to 0.060 per cent of nitrogen. In every case the sudden attainment of brittleness corresponds to a change in the structure.

A percentage of 0.060 nitrogen is very rare in commercial steels, but 0.030 to 0.040 per cent frequently appears. For this reason hard steels become brittle much more easily than softer grades, since the proportion of nitrogen required to cause the effect occurs more frequently in practice.

Nitrogen appears also to produce a considerable effect upon tempered steels. The nitride of iron in such cases appears in solution in the martensite, as it does in the ferrite for the annealed steels. The influence of nitrogen upon the electric and magnetic properties of steel is also distinct. In the case of soft iron the coercitive force and the hysteresis are increased.

In commenting upon these remarkable researches of M. Braune, M. Le Chatelier observes that their importance will be evident to every metallurgist. The appearances noted in the metallographic observations of M. Braune have been noticed

before, but it has remained for him to discover their origin. An interesting fact is that the fixation of the nitrogen by the iron does not occur directly by a combination with the nitrogen of the atmosphere, and the presence of a basic slag appears to be necessary as a reducing medium. This corresponds closely with the process of the formation of the cyanides, and indeed it has already been observed that blast furnaces which produce much cyanide of potassium also produce an inferior quality of iron. The nitrogen is acquired by the metal principally in the blast furnace and in the basic converter.

The experiments of M. Braune show that the fixation of the nitrogen is effected more readily from ammonia than from the cyanides. The ease with which the cyanides are transformed into ammoniacal compounds in the presence of moisture renders it probable that the vapor of water may be an intermediary in the introduction of the nitrogen into the metal. This view is confirmed by the experience of M. Guillet in the cementation of nickel steel, it appearing that the use of a moist cementing material is injurious. With a dry material for the cementation, the interior of the case-hardened pieces shows no brittleness, which is not the case with a moist substance.

The importance of these studies cannot be over-estimated, and if, as appears probable, M. Braune has discovered the true cause of brittleness in iron and steel, the way to prevent the combination of nitrogen with the metal will doubtless be found by practical metallurgists and manufacturers. After the way has been blazed, every succeeding traveler broadens the path, and in this, as in other departments of applied science, the operative departments of an industry are prompt to avail themselves of the discoveries which are made in the laboratory. If the cause of brittleness has actually been discovered, its removal is only a matter of time, and the far-reaching consequences of the discovery cannot now be limited.

Fractures in Large Steel Boiler Plates.* — Practically the only material which has been used for the plates of marine boilers for many years is mild steel. The question has been

* From a paper read by J. T. Milton at the summer meeting, July, 1905, of the British Institution of Naval Architects. Mr. Milton is chief engineer surveyor to Lloyd's Register. "The Iron Age," August 24, 1905.

recently raised whether the present tests applied to structural steel are sufficient to determine absolutely its quality. It may be at once conceded that the present method of testing cannot determine all the qualities of the steel. What the present system does is to test the tensile breaking strength; sometimes, also, but not often, its yield point; it also determines its ultimate extension, its freedom from taking a temper and its capability of withstanding cold bending. If the properties tested are all found to be normal, it is assumed that all the other mechanical properties will be equally satisfactory and that the material is of good quality. Recent researches, however, show that the tests usually applied may all yield good results, and yet the steel may be unsatisfactory in its resistance to impact or in its endurance of fatigue caused by repeated applications of a stress considerably below the ordinary breaking strength.

In regard to the question of overheating and rolling at too high a temperature, one of the large steel makers of this country made the following experiment: One large ingot of boiler quality was cut up. Three pieces were rolled into 1-inch plate, one being rolled at what is considered to be the proper temperature, one at too high a temperature and one too cold. Pieces were also rolled at normal temperatures and too cold into $\frac{1}{2}$-inch and $\frac{1}{4}$-inch plates. The pieces of plates thus made were in some cases overheated and allowed to cool and in other cases they were "normalized" — that is, they were heated to bright red and allowed to cool out (the ordinary method of annealing plates); in other cases they had no heat treatment. They were then tested. The results are very interesting and seem to confirm the opinions expressed by the experimenter, — namely, that when the steel is initially good, heating the ingot between wider ranges of temperature than should occur in practice with even no more than ordinary care does not have a very prejudicial effect on either the ordinary mechanical tests or even on fatigue tests, the terms "too hot" and "too cold" in these tests referring to such extremes of temperature as would scarcely occur in actual work without very gross carelessness. Further, neither does overheating the finished plates seem to injure them seriously. On the contrary, in some cases it appears to have actually increased their ductility. It must be stated, however, that the experimenter expresses the opinion that in plates where there is con-

siderable segregation the segregated parts might behave very differently under the various heat conditions. Some segregation must exist in all ingots, and therefore also in all plates rolled out of a whole ingot; but when the segregation is slight, seeing that it must occur in the middle of the thickness of the plate near the neutral axis as regards bending stresses, the plates, although inferior to those without segregation, might not be unfit for use.

In view of the very large size of boiler shell plates as now made, it is important to know whether these large plates can be made free from initial strains or whether it is inevitable that they should have some strains in them when they are made. Seeing that large plates can be made perfectly flat and free from internal strain it is reasonable that engineers should refuse to receive those that are rolled, buckled or wavy, and should insist that in such cases the steel makers should flatten the plates by taking out the buckles or waves and afterward anneal the plates. Plates should always be delivered to the boiler makers in such a condition that they can use them with confidence without any preliminary straightening treatment. Besides the bad rolling referred to, another cause of initial stresses in plates may be their unequal cooling on the mill floor. That this can occur is generally considered to be improbable, but it must be admitted that it is not impossible.

It is earnestly desired that steel makers especially, who have such exceptional opportunities for studying all the properties of the material they make in such large quantities, will absolutely solve the problem why in very rare cases some material of good sound chemical quality, made apparently in the proper way, becomes possessed of such abnormal properties as to become utterly unfit for the purpose for which it is made.

High-Duty Cold Saw with Teeth of High-Speed Steel.* — A special design of high-duty circular saw which enables high-speed steel to be used for the teeth has been designed for cutting steel castings and forgings, structural steel, armor plate, etc., and is illustrated herewith. The blade is a disk of high-carbon crucible steel, and is of sufficient stiffness to withstand any pressure that can be safely put upon the teeth. In each face there are slots for the teeth, and the slots are inclined backward from

* " Engineering News," October 19, 1905.

radial lines at such an angle that the pressure on the teeth when cutting has a locking effect; as the resultant of the pressure tends to force the teeth inward, and as there is no tendency to draw them by the cut, the teeth do not require to be pinned or bolted or otherwise fastened in place. The teeth are of simple design, forged from the bar stock in a plain die. As no machine work is required to shape or fit them, the teeth can be made of the modern high-speed steels, while in saws where the teeth have to be drilled, shaped, etc., ordinary tool steel has to be used and tempered. It will be seen also that this saw has the special feature of dividing the cut, the teeth being placed (in staggered position) on each side of the blade and slightly overlapped, so that each tooth alternately takes half the width of the cut. The teeth have a slight outward inclination, so as to make the cut clear the saw blade, the points of the teeth being the only part of the saw which touch the work. A broken tooth can be quickly driven out by a chisel inserted in the semicircular recess at the bottom of the slot, and a new tooth at once put in its place.

The Midvale Steel Company has a saw of 73 inches diameter for an armor-plate cold-sawing machine. The blade or disk is 70 inches diameter and $1\frac{1}{8}$ inches thick, with 30 teeth on each side, the teeth being inclined 20 degrees back of the radial line, and having an outward inclination of 1 degree, so as to make a cut $1\frac{5}{16}$ inches wide. The teeth are of a special grade of steel made by the Midvale Steel Company, and have an angle of 60 degrees for their cutting edges. A 5-inch nickel-steel plate (unhardened) has been cut with a feed of 40 inches per hour, while a $4\frac{1}{2}$-inch hardened steel armor-plate has been cut with a feed of 9 inches per hour. The blade is bolted to a collar on a mandrel, and the machine is directly geared to a 50-horse-power electric motor, change gears giving six peripheral speeds of 10 to 40 feet per minute.

These saws are made by the Tindel-Morris Company, of Eddystone, Pa. At the company's works they have been in use for over three years without any cost for repairs. With machines of sufficient power for the work, feeds of $\frac{1}{2}$ inch to $1\frac{1}{4}$ inches per minute are used on castings, forgings, bridge pins, structural steel and other material in which the carbon does not exceed 0.40 per cent. The peripheral speed for the same kind of material is about 50 feet per minute.

The Influence of Carbon, Phosphorus, Manganese and Sulphur on the Tensile Strength of Open-Hearth Steel.* — The formulas established by Mr. Campbell require the use of tables in order to take into account the influence of manganese on the tensile strength of steel. On examining these tables I find that the quantities given therein may be expressed by simple algebraic forms, so that formulas for tensile strength may be written which can be used without the help of tables.

Referring to the case where the carbon is determined by combustion, Mr. Campbell's formula for the tensile strength of acid steel in pounds per square inch is

$$40{,}000 + 1{,}000\ C + 1{,}000\ P + x\text{Mn},$$

in which C and P are the amounts of carbon and phosphorus in units of 0.01 per cent, while xMn is to be taken from his Table VII. This table is one of double entry, the arguments being the amounts of carbon and manganese. Taking Mn also as the amount of manganese in units of 0.01 per cent, I find that the values of xMn given in this table are expressed by

$$x\text{Mn} = -320\ C + 8\ \text{CMn},$$

and accordingly the formula for tensile strength of acid steel becomes

$$40{,}000 + 680\ C + 1{,}000\ P + 8\ \text{CMn},$$

which may be used without referring to a table. For example, let carbon be 0.50 per cent or C = 50, phosphorus be 0.05 per cent or P = 5 and manganese be 0.45 per cent or Mn = 45; then the tensile strength of the acid steel is 97,000 pounds per square inch.

For basic steel, carbon being determined by combustion, Mr. Campbell's formula for tensile strength is

$$41{,}500 + 770\ C + 1{,}000\ P + y\text{Mn},$$

in which yMn is taken from his Table XIII, according to the proportions of carbon and manganese present. For this case I find

$$y\text{Mn} = -2{,}700 - 120\ C + 90\ \text{Mn} + 4\ \text{CMn},$$

and hence the formula for tensile strength of basic steel becomes

$$38{,}800 + 650\ C + 1{,}000\ P + 90\ \text{Mn} + 4\ \text{CMn},$$

which may be used for direct computations. For example, let

* Mansfield Merriman. "A Discussion of the paper by H. H. Campbell." Transactions, American Institute of Mining Engineers.

carbon be 0.30 per cent or C = 30, phosphorus be 0.01 per cent or P = 1 and manganese be 0.45 per cent or Mn = 45; then the tensile strength of the basic steel is 68,750 pounds per square inch.

The last term of each of these formulas contains the product of C and Mn, and hence the formulas do not, perhaps, clearly exhibit at first sight the influence of carbon upon the tensile strength. They may, however, be written in the forms:

for acid steel, 40,000 + (680 + 8 Mn)C + 1,000 P;

for basic steel, 38,000 + (650 + 4 Mn)C + 1,000 P + 90 Mn.

It is now clearly seen that each 0.01 per cent of carbon adds to the tensile strength a number of pounds per square inch, which is expressed by 680 + 8 Mn for acid steel and by 650 + 4 Mn for basic steel. Thus, if manganese is 0.50 per cent or Mn = 50, then each 0.01 of carbon adds 1,080 pounds per square inch to the strength of acid steel and 850 pounds per square inch to that of basic steel.

The formulas also show that each 0.01 per cent of manganese adds to the tensile strength a number of pounds per square inch, which is expressed by 8 C for acid steel and by 90 + 4 C for basic steel. Thus, if carbon is 0.30 per cent or C = 30, then each 0.01 per cent of manganese adds 240 pounds per square inch to the strength of acid steel and 210 pounds per square inch to that of basic steel.

The algebraic expression of the influence of carbon and manganese on the strength of open-hearth steel is probably only one of the important results which may be deduced from the valuable paper of Mr. Campbell, for long-continued careful records of actual facts will always deserve careful study.

The Minette District in France.* — The recent development of the steel industry of France, followed by the appearance of some of the leading works as sellers in the international markets, is coincident with the rapid opening up of the Minette district along the borders of Luxemburg and Lorraine. A recent report by H. Cousin, published by the Comité des Forges de France, presents some interesting figures which deal with the output of the Department of Meurthe-et-Moselle in 1904. The iron mines may be divided into two groups, that of the basin of Nancy and that of the basin of Briey and Longwy. In 1904 the

* " Iron Age," October 19, 1905.

mines in the Nancy district produced 1,711,770 metric tons, as compared with 1,668,533 tons in 1903. It is not expected that an important increase will take place in the future. It is in the Longwy section, with its outcrop mines, and in the Briey section, with its deep mines, that a further rapid growth is looked forward to. In 1904 the production of the Longwy-Briey basin was 3,821,437 tons, an increase of 588,306 tons over 1903. Adding the output of the quarries, the production of iron ore for the Department of Meurthe-et-Moselle was 5,951,274 tons, an increase over 1903 of 658,931 tons. The shipments to other departments in France and to Belgium, Luxemburg and Germany amounted to 1,043,000 tons. The average value at the mines was 3.51 francs per ton. The total number of men employed was 6,075, to whom wages aggregating 8,877,275 francs were paid. In the Longwy-Briey basin miners average 6 to 7 francs per day, but many of them earn more than 10 francs, or $2 per day. Cutting machinery is being employed, Morgan Gardner chain machines being in use at the Maron-Val-de-Fer and the Mont-Saint-Martin mines. They are electrically driven.

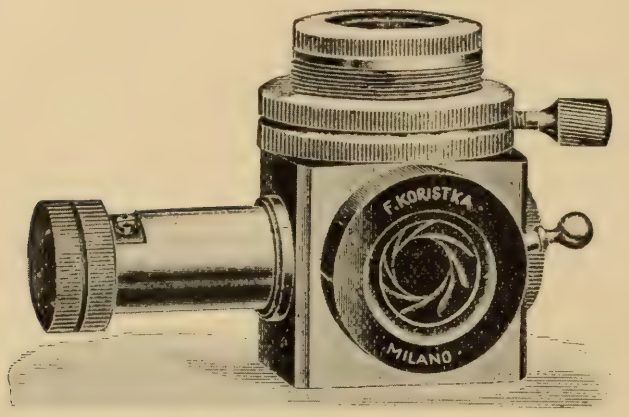
American Institute of Mining Engineers. — Under date of September 22, 1905, the secretary of the American Institute of Mining Engineers has issued a circular from which the following is extracted:

I. — South Bethlehem Meeting, February, 1906. The ninetieth meeting of the Institute, for the reading and discussion of papers, will be held at Lehigh University, South Bethlehem, Pa., beginning Wednesday, February 21, 1906. Further particulars will be given by circular hereafter.

II. — Joint Meeting in England next year. The Council of the Iron and Steel Institute has cordially invited the American Institute of Mining Engineers to hold in England, during the autumn of 1906, a joint meeting, consisting of sessions in London, followed by excursions to the provinces. This invitation has been accepted by our Council. It is understood that the meeting will take place in August or September, but the precise date has been left open for early determination after further conference. Particulars concerning this and other features of the meeting will be given in a later circular. This brief preliminary announcement is issued in order that members may have as long

a time as possible to make such arrangements for next year as will permit their attendance.

Koristka's Illuminator for Opaque Objects. — This apparatus is principally intended for the study of metals. It is screwed to the microscope tube, and contains a total reflexive prism which receives the light from the front and directs it by means of the objective on to the preparation. The prism occupies only half the field, thus leaving the other half free for vision. An iris diaphragm placed in front of the prism serves to regulate the light which it is to receive. By pulling out the arm which carries the prism the latter may be removed from the optic field, so as to leave it quite free. For use with this illuminator a lens of 35 mm. diameter, and 72 mm. focus is recommended.



University of Wisconsin. — In the College of Engineering of the University of Wisconsin a new course in chemical engineering has recently been established. It is the purpose of this course thoroughly to train students in the fundamental principles of both chemistry and engineering and to give such other subjects as will, so far as possible, contribute toward a liberal education.

Coal Production in 1904. — Mr. Edward W. Parker, of the Division of Mining and Mineral Resources of the United States, reports a production of all kinds of coal in the calendar year 1904 of 314,562,881 gross tons, of which 65,318,490 gross tons were Pennsylvania anthracite and 249,244,391 gross tons were bituminous. The value of the anthracite coal was $138,974,020 and that of the bituminous coal $305,842,268. The average price per gross ton for the marketed sizes of anthracite coal in 1904 was $2.35 per gross ton and for the bituminous coal $1.10.

REVIEW OF THE IRON AND STEEL MARKET

October has not shown the excitement in finished material markets which characterized September, but new business has, in general, been greater than production. In the cruder materials, on the other hand, there have been sharp advances, and much excitement prevails. Standard Connellsville furnace coke has advanced to $3.00 at ovens and is scarce even at that figure. Pig iron has advanced a full dollar a ton since our last report, but coke at $3.00 a ton is not in harmony even with the advanced price of say $16.00 at furnace, as it is a dictum in the trade that a proportion of about seven to one should be regarded as about normal.

There is a serious shortage of crude steel, Bessemer billets being higher, while open-hearth billets are scarcely to be had at any price. There is less "surplus" steel than usual, a larger percentage of ingot production going directly into finished lines at the seat of steel production.

Never has the outlook been better in the steel trade. While there is some uneasiness on account of the rapid advances in coke and the prospect of higher prices on pig iron, finished steel prices have been held in line very well, a very conservative policy being followed. It was expected that plates and merchant steel bars would be advanced, but the matter of a plate advance was definitely settled in the negative at a meeting of the mills, while it is well understood that the idea of advancing steel bars has been given up.

The railroads have been heavier buyers in the past few months than ever before, placing very large orders for rails, locomotives and steel cars. Railroad buying is the basis of the present extreme activity, but other consumptive lines furnish good support. Pig-iron production in 1905 will exceed 22,000,000 tons, or 4,000,000 tons beyond any previous record. It is now at substantially the maximum rate with the present equipment, and it would require considerable further advance to bring in some capacity which can be operated only under high prices.

Pig Iron. — The whole pig-iron market has advanced about a dollar a ton since our last report. Buying has not been heavier, in general, than in September, but furnaces found themselves almost sold up for this year and with large sales for next year, and with coke advancing rapidly felt justified in advancing their prices. The United States Steel Corporation has bought, since about the beginning of September, a total of 120,000 tons of Bessemer pig iron, for September, October and November delivery, at from $14.50, valley, on up to $16.00, which price was paid for November delivery. The corporation is likely to buy iron for November and December very shortly. These purchases are significant in that they take a great deal of iron out of the market, and show that the corporation is making steel to maximum capacity, its own production of pig iron being normally sufficient. The tonnage is small, relative to the corporation's own production, since it makes about 30,000 tons a day. Prices are very firm as follows: F.o.b. valley furnace, Bessemer and basic, $16.00 to $16.50; No. 2 foundry, $16.00 to $16.50; forge, $14.75 to $15.25. Delivered Pittsburg: Bessemer and basic, $16.85 to $17.35; No. 2 foundry, $16.85 to $17.35; gray forge, $15.60 to $16.10. F.o.b. Birmingham, delivery before April 1: No. 2 foundry, $13.00; gray forge, $10.75; for delivery beyond April 1, furnaces are asked from 50 cents to $1.50 more. Delivered Philadelphia: No. 2 X foundry, $17.50 to $17.75; standard gray forge, $15.75 to $16.00. Delivered Chicago: northern No. 2 foundry, $17.75 to $18.00; malleable Bessemer, $17.75 to $18.00. Freight: Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65; to Philadelphia by water, $3.50; by all-rail, $4.00.

Steel. — There has been but very little crude steel available in the open market, while the demand has been quite heavy. The advance in the market has been limited by what consumers could afford to pay, having regard to prices obtainable for their finished product. Bessemer billets can be quoted at $26 f.o.b. Pittsburg, or $1.00 advance since our last report. Open-hearth billets can scarcely be quoted, as there are none offered. Forging billets would bring about $30. Sheet bars are nominally $27 for long lengths. Rods are $32 for wire rods and $33 for chain rods. All prices are f.o.b. Pittsburg.

Rails. — There has been further booking of rail orders, and

with tonnage which will be held over the rail mills have about 2,000,000 tons sold for next year, while production will likely exceed 3,000,000 tons, about the record so far, by a wide margin. The Chicago mill is booked through November, and the Alabama and Colorado mills about through the year, the eastern mills being less fully sold up. The price remains at $28, f.o.b. mill, in 500-ton lots and over. Light rails have been advancing, and are now very firm at $26 to $27 for sections 25 to 45 pounds per yard, the higher figure being for early delivery.

Shapes. — The market has been fairly active, a large tonnage being booked for next year for definite construction undertakings. The large mills are filled with specifications into next year, and premiums are freely paid for small lots for early shipment. Prices remain based on 1.70 cents for beams and channels, 15-inch and under, angles and zees.

Plates. — The Pennsylvania Railroad system in October placed orders for 21,000 steel freight cars, following orders for 16,000 in September, and making 37,000 cars for this system for 1906 delivery. Other roads have been good buyers, and the steel car plants are filled until some time in the third quarter of next year. The leading maker, the Pressed Steel Car Company, is increasing its capacity, and next year will have a nominal capacity of 150 cars daily. Its tonnage arrangements with the Carnegie Steel Company are being rearranged, and beginning January 1 it will receive from this company about 65,000 tons monthly of rolled steel materials, chiefly plates, against about 45,000 tons at present. The plate mills did not advance prices at their October meeting, and no advance is now likely for the present, and we quote regular mill prices on the basis of 1.60 cents for tank quality, with premiums ruling for early delivery.

Merchant Bars. — The expected advance in price of steel bars has not been made and is not likely to be considered for the present. We quote Bessemer and open-hearth at 1.50 cents, base, Pittsburg. Common iron bars, f.o.b. Youngstown, remain at 1.70 cents, or 1.75 cents, Pittsburg. The Chicago market has advanced sharply, and is now 1.80 cents, Chicago.

Sheets. — The market is now quite steady, but has not regularly advanced. Mills are fairly well sold for a few weeks ahead, and in some cases to the end of the year. There are still some sellers at former quotations, 2.25 to 2.30 cents for black and

3.30 to 3.35 cents for galvanized, No. 28 gauge, in carload lots with desirable specifications, the largest lots being at a concession of not more than 5 cents a hundred from these quotations.

Wire Products. — The market is very firm, and production is up to the capacity of the mills. Prices have been advanced to $1.00 a ton all around, and we now quote, in carload and larger lots to jobbers: plain wire, 1.65 cents base; wire nails, $1.80 base.

Scrap. — Light sales have advanced heavy melting stock to $17, delivered Pittsburg, and a still higher market is expected by dealers who have accumulated scrap against the winter. We quote other grades advanced as follows, delivered Pittsburg: Cast borings, $10.25 to $10.75; sheet scrap, $14.50 to $15.00; No. 1 cast scrap, $15.50 to $16.00.

STATISTICS

The Production of Steel-Hardening Metals in 1904.* — WASHINGTON, D. C., September 12, 1905. — The United States Geological Survey has completed an unusually elaborate report upon the production of steel-hardening metals in 1904, compiled by J. H. Pratt, which shows a total output of metal ores, or concentrates, amounting to 945 net tons, valued at $259,620, including the production of titanium valued at $7,000, the quantity of which is not stated. This was a decrease in both quantity and value as compared with 1903, but a very large increase over 1902. Over three fourths of the output of 1904 was credited to tungsten ores. The states producing these steel-hardening metal ores, in the order of the value of their production, together with the metallic ore mined, are Colorado (tungsten, uranium and vanadium), Arizona (tungsten and molybdenum), California (chromium), Washington (molybdenum), Missouri (nickel and cobalt) and Virginia (titanium).

In the following table is given the production in the United States of ores of these metals for the years 1903 and 1904:

	1903		1904	
Mineral	Net Tons	Value	Net Tons	Value
Chromium	168	$2,250	138.0	$1,845
Molybdenum	795	60,865	14.5	2,175
Nickel and cobalt	661	273,900	23.0	54,000
Titanium	...	.....	...	7,000
Tungsten	292	43,639	740.0	184,000
Uranium and vanadium	30	5,625	44.5	10,600
Totals	1,946	$386,279	960.0	$259,620

NICKEL AND COBALT

The main supply of nickel and cobalt produced in the United States in the last few years has been obtained from Mine Lamotte, Mo., as a by-product in lead smelting. During 1904, however,

* "The Iron Age," September 14, 1905.

there was no actual production of any metallic nickel or cobalt oxide, but there was obtained 3,600 net tons of low-grade material, valued at $54,000, ready to be smelted and refined. This contained approximately 24,000 pounds of metallic nickel, valued at $11,400, and 22,000 pounds of cobalt oxide, valued at $42,600. In Virginia and North Carolina a considerable tonnage of low-grade ore was produced in development work at deposits located at Hemlock, Floyd County, Va., and near Webster, Jackson County, N. C. None of this, however, was shipped during the year.

Nearly all of the nickel used in the United States is obtained from Canada, with a small quantity from New Caledonia. For this reason the production of nickel ore in Canada is of especial interest to the users of the metal in the United States. In 1903 the nickel output aggregated 12,505,510 pounds. In 1904, however, there was a falling off of approximately 2,000,000 pounds as compared with the nickel content of the matte in 1903. A better quality of matte, containing a much larger percentage of nickel, has been obtained during the last few years.

Imports and Exports of Nickel

There was quite a falling off in the importation of nickel compounds and matte, etc., during 1904, the quantity imported into the United States in 1904 being 19,739,315 pounds, valued at $1,122,491. As compared with the importation of 1903 of 36,217,985 pounds, valued at $1,493,889, it is a decrease of 16,478,670 pounds in quantity, but of only $371,398 in value. This very large decrease in quantity, with only a comparatively small decrease in value, is due to the higher grade matte that is imported. The importation of cobalt oxide in 1904 amounted to 42,354 pounds, valued at $86,925. Besides this cobalt oxide there was imported 330,983 pounds of cobalt ore and metallic cobalt, valued at $18,272, making the total value of the importation $105,197.

As would naturally be expected, considering that a very large part of the Canadian production of nickel matte is consumed in this country, there is exported each year from the United States a considerable quantity of nickel, and in 1904 this amounted to 7,519,206 pounds, valued at $2,130,933.

Chromium

California is still the only state producing any chromite, and in 1904 the quantity was 123 gross tons of ore, valued at $1,845. As compared with the production in 1903 this is a decrease of 27 tons. Practically all of the chromite consumed in the United States is imported, the greater quantity being obtained from Turkey, with smaller quantities from New Caledonia and Canada. The Canadian deposits of chromite are located in the province of Quebec and in Newfoundland, and in 1904 the total production of Canadian chrome ore amounted to 6,074 net tons, valued at $67,146, an increase of 2,691 tons as compared with 1903. Nearly all of the chromite produced was shipped to the United States.

Tungsten

In 1904 there was produced 740 net tons of tungsten concentrates, valued at $184,000, as compared with 292 tons in 1903. The 1904 production was obtained from 10,975 tons of crude ore. During the last few years there have been small quantities of tungsten ores and alloys imported into the United States, but as the tungsten ores are admitted free of duty it has been impossible to obtain the statistics for them. In 1904 the imports of a ferro-tungsten-chromium alloy amounted to $29,439 in value, as compared with $18,136 in 1903 and with $7,046 in 1902.

There has been an increasing demand for this metal during the last year or two, stimulating the prospecting for tungsten ores, which has resulted in the discovery of a number of new localities where these ores are to be found. Thus tungsten, which was formerly considered one of the rather rare elements, has been proved to occur in large quantity and to be rather widespread in its occurrence. The principal deposits found are in Arizona, Nevada and Colorado, with others worked to but a small extent in Idaho, Montana, New Mexico, Oregon, South Dakota and Washington. In the Eastern states the principal deposits are located in Connecticut, and a very small quantity has been found in North Carolina.

The only form in which the metallic tungsten has been prepared for market is as the black powder obtained by the chemical reduction of the ores, and in this country this reduction is carried on principally by the Primos Chemical Company, Primos,

Pa. Fused metallic tungsten has not as yet been made commercially by any of the processes by which many of these steel-hardening metals have been obtained. Hence at the present time tungsten steel is manufactured either by the introduction of this powdered metallic tungsten or by the addition of the ferro alloy. The ferro alloy cannot be produced in the blast furnace on account of the high temperature required, and therefore the electric furnace has been used, in which the tungsten concentrates are reduced directly to the ferro alloy. Besides the ferro-tungsten alloys there are a number of alloys of tungsten with iron and nickel, with iron and chromium and with nickel.

Molybdenum

The production of molybdenum ores in the United States is still very small, and in 1904 there was reported only 14½ net tons, valued at $2,175. There is still considerable uncertainty among producers of molybdenum ores as to the value of these ores, and prices are quoted as ranging from $100 to $3,000 per short ton. The actual value, however, of molybdenum concentrates at New York is probably about $200 to $250 per net ton. The sources of supply of molybdenum are the two minerals — molybdenite, the molybdenum sulphide (MoS_2), and wulfenite, the lead molybdate ($PbMoO_4$). In the United States the two principal deposits of this mineral that have been thus far exploited are in the vicinity of Crown Point, Chelan County, Wash., and at Cooper, Washington County, Me.

Uranium and Vanadium

Although considerable development work was done in 1903 and 1904 upon uranium and vanadium deposits, the actual production of ores of these metals was very small, amounting in 1904 to 44½ net tons of concentrates and partially concentrated ore, valued at $10,600. The imports of uranium salts in 1904 were valued at only $9,024, as compared with imports valued at $13,498 in 1903 and at $12,491 in 1902.

Of these two metals, uranium and vanadium, it is only the latter that has been used in the manufacture of steel, although uranium has been tested and experimented with to some slight extent for this purpose. No large quantity of vanadium steel

has been made and there is but very little of it on the market, although the ferro alloys are now being made and offered for sale. The metal uranium is included with the steel-hardening metals on account of the experiments that have been made with it for this purpose; also on account of its close relation to vanadium and because so many of the ores of vanadium contain uranium. All of the uranium minerals have become of special interest in the last year or two since the discovery of radium, as uranium seems to be the source of radium.

Titanium

The production of titanium, or rutile, during the year 1904 was valued at approximately $7,000. Although the actual commercial value of titanium as a steel and iron hardening metal has not as yet been thoroughly demonstrated, still the experimental work that has been done seems to indicate that titanium will become of some importance in the production of both coke and charcoal iron.

The World's Production of Finished Iron.* — In our issue of July 20 reference was made to the production of rolled iron in the United States in 1904, which amounted to 1,760,084 gross tons. This total compared with 2,518,194 tons for 1890, the last preceding year in which the statistics of rolled iron production had been gathered separately from those of steel. The London "Iron and Coal Trades Review" combines these figures with those of other countries and to the discomfiture of the prophets of the extinction of the puddling industry. The production of rolled iron in leading countries in the past two years is thus stated:

	1903	1904
United Kingdom (gross tons)	950,390	936,228
Germany (metric tons)	819,832	765,197
France (metric tons)	589,910	554,632
Belgium (metric tons)	401,550	360,520
Russia and other European countries (metric tons)	850,000	800,000
Totals	3,611,682	3,416,577
Add United States (gross tons)	.....	1,760,084
Grand total	.....	5,176,661

* "The Iron Age," August 24, 1905.

Estimating that with all countries included the world's production of rolled iron was about 6,000,000 tons last year, our contemporary points out that there has certainly been no extinction of the finished iron industry and that these products are evidently as much appreciated as they ever were and deemed quite as indispensable.

In 1880 the output of finished iron in the United Kingdom, the United States, Germany, France, Belgium, Austria-Hungary, Russia and Sweden was 8,553,225 tons, and in 1890 8,340,599 tons. Last year the world's output of steel ingots was about 36,000,000 tons, so that the ratio of steel to iron was substantially 6 to 1.

RECENT PUBLICATIONS

The Crystallization of Iron and Steel, by J. W. Mellor. 144 4 × 7½-in. pages; illustrated. Longmans, Green & Co. New York. 1905. Price, $1.60. — In this little book the author has attempted with a marked degree of success, to present clearly and concisely the fundaments of modern metallography. The subject is treated in a logical order, the author describing in turn the constitution of alloys in general, the constitution of iron and steel, the rational of the hardening, annealing and tempering of steel, and the influence of stress and strain. This is followed by a description of the preparation of samples of metals for microscopical examination and by the glossary of terms drawn in 1901 by the Iron and Steel Institute. The book also includes a well prepared index. The photomicrographs reproduced to illustrate typical structures have generally been selected with care and are chiefly from Arnold, Stead and Osmond. On page 15 and others, the author, in explaining the allotropic theory, evidently attributes the hardness of suddenly cooled steel to the retention of gamma iron, whereas in the light of Osmond's recent work, gamma iron (austenite) is relatively soft, the hardness of quenched steel being due to the presence of beta iron in the form of martensite. The author in a foot-note, however, expresses his doubt as to whether it is gamma or beta iron which renders steel hard, but he adds that these are both supposed to be hard. On page 54 he states that "gamma iron is said to be as hard as chilled steel." The illustration facing page 23 and representing the structure of granular pearlite (sorbite) after Heyn, was not selected with the care shown in the choice of the other photomicrographs, seeing that many photomicrographs of this kind have been published of much greater excellence. It is, we think, to be regretted that the author has not used the happy term "eutectoid" in place of "eutectic" and "saturated" to designate steel having a eutectic-like constitution that is made up exclusively of pearlite, as suggested by Professor Howe. On page 32

the author gives a classification of substances which should be very helpful to students of metallography as it brings out clearly the nature both of eutectic mixtures and of solid solutions. The classification is as follows:

Heterogeneous	Indefinite proportions			Ordinary mixture
	Definite proportions			Eutectic mixture
Homogeneous	One component			Element
	More than one	Definite proportions		Chem. compounds
		Indefinite proportions	Liquid	Liquid solution
			Solid	Solid solution

On page 33 and others the solid solution of carbon in iron (in gamma iron) which is stable at a high temperature (above the critical range) is called martensite by the author, whereas we believe that this constituent should be called "austenite" according to the views of Osmond and other authoritative writers, and the name of martensite reserved for the solid solution of carbon in beta iron, the ordinary constituent of hardened steels. It is much to be regretted that such confusion and divergence of opinion should still exist among metallographists on so vital a point, while there seems to be no good reason for it. On page 64 Arnold's experiments by which he endeavored to show that there was no marked increase in the tenacity at the Ar_3 and Ar_2 points are apparently indorsed by the author, who ignores the discussion of these experiments by which it was revealed that on the contrary a decided and abrupt increase of tenacity did take place at these points. On page 67, referring to a steel crystal from Tschernoff's collection, 15 inches is given as the equivalent of 15 cm., evidently through a typographical error. The length of the crystal was about 15 inches. On page 69, it is stated that when an hypereutectoid steel cools "the pearlite behaves like a pure metal, and rejects the excess of cementite to the boundaries, so as to form a network of cementite. Is it not cementite that forms first (falls out of solution), and would it not be more correct to say that the excess of cementite is rejected by the *austenite* (the mother metal) and that later each mesh of austenite (which has now reached the nature of hardenite) changes *in situ* into pearlite?

This book is a very valuable addition to metallographic literature and it may be warmly recommended as a textbook for all students interested in this growing subject.

Metallurgy of Cast Iron, by Thomas D. West. Ninth edition. 677 5 × 7-in. pages; illustrated. The Cleveland Printing

and Publishing Company. Cleveland, Ohio. 1904. Price, $3.00. — The fact that this is the ninth edition of this well-known book is in itself a testimony of its worth and popularity.

Laboratory Chemistry, by Richard B. Moore. 195 5 × 7-in. pages; illustrated. J. B. Lippincott & Co. Philadelphia. 1904. Price, 75 cents. — The purpose of this little book is to briefly describe the fundamental principles of physics and chemistry and to illustrate them by means of simple experiments to be performed by the student. The book is written for the use of students in secondary schools.

Laboratory Notes on Practical Metallurgy, by Walter MacFarlane. 140 5 × 7-in. pages; illustrated. Longmans, Green & Co. New York. 1905. — In this excellent little book the author describes one hundred and twenty-seven experiments illustrating chemical principles of interest to metallurgists. They are for the most part of a simple character and such as can readily be performed with the ordinary equipment of the chemical laboratories of technical schools.

Coke, a treatise on the Manufacture of Coke and Other Prepared Fuels and the Saving of By-products, by John Fulton. 476 6 × 9-in. pages; illustrated. International Textbook Company. Scranton, Pa. 1905. Price, $5.00. — In this, the second and revised edition of his book, the author has brought up to date the description of an industry of vast and growing magnitude. The subject is divided into eleven chapters which are fully and carefully illustrated, while the typography of the book is very satisfactory. That this is the best and most exhaustive treatise, in the English language at least, dealing with the manufacture of coke will, we believe, be generally conceded.

The Copper Handbook, by Horace J. Stevens, Volume V (1904). 882 6 × 8½-in. pages; illustrated. Houghton, Mich. 1905. Price, in buckram binding, $5.00; in full morocco, $7.50. — Each annual issue of this valuable publication is more exhaustive than the preceding one. The present volume is divided into sixteen chapters, dealing respectively with the history, geology, chemistry, mineralogy, metallurgy and uses of copper, glossary

of mining terms, copper deposits of the United States, of Canada and Newfoundland, of Europe, of Africa, of Asia, of Australia and Oceanica, copper mines of the world and statistics of copper. This is followed by a carefully prepared index.

In the present edition the two final chapters which are the most important and constitute five fifths of the entire book have been completely rewritten.

The fifteenth chapter contains no less than 3,849 titles, with from two lines to fourteen pages devoted to each. The editor writes that of the many companies denounced as dishonest or downright fraudulent in the last edition of this book, not one has been able to prove its right to a better rating than was accorded it, though a number have made attempts to secure such ratings, by methods ranging from covert bribery, through legal proceedings, down to threats of physical violence. Of the many companies indorsed as honorable in the past four annual editions of the copper handbook, only one has been found dishonest. It will be apparent that the contents of this book are invaluable to all those interested in copper, whether their interest be technical or financial.

Friction and Lubrication, by William M. Davis, second edition. The Lubrication Publishing Company. Pittsburg, Pa. — The important subject of lubrication and lubricants is treated in this book with much authority and in a thoroughly practical manner, the book being written essentially for the mechanical man. The author tells us that he has kept in mind the fact that engineers and managers and mechanics are busy men and that he has therefore tried to present the matter in a plain, concise way, that will be readily understood by readers and be of practical value in their every-day work.

Machine-Shop Tools and Methods, by W. S. Leonard. 554 6 × 9-in. pages; nearly 700 illustrations. John Wiley & Sons. New York. 1905. Price, $4.00. — This book was written principally as a textbook for his students by the author, who is instructor in machine-shop practice in the Michigan Agricultural College, but it will be found of great value by all those interested in machine-shop work. It undoubtedly fills a place in technological literature not heretofore occupied. Tools, machines and

manipulations are clearly and methodically described, while the book is finely printed, illustrated and bound. Three hundred and forty-seven well selected questions are appended to the book and should prove of much value to the student.

Mechanics of Materials, by Mansfield Merriman. Tenth edition, rewritten and enlarged. 507 6 × 9-in. pages; illustrated. John Wiley & Sons. New York. 1905. Price, $5.00. — This is the tenth edition of Professor Merriman's well-known book. In the present edition the book has been rewritten and enlarged from 329 to 518 pages. According to the publisher's notice, the main purpose in rewriting the book has been to keep it abreast with modern progress, but the attempt has also been made to present the subject more clearly than before, in order to advance the interests of sound engineering education and to promote sound engineering practice. This new edition of so important and popular a work will undoubtedly be welcomed by the engineering profession. The name of the publisher is a guaranty of excellent typography, binding and general make-up of the book.

BOOKS RECEIVED

The following books have been received and will be reviewed in an early issue of the *Iron and Steel Magazine*.

Cours d'Exploitation des Mines, third edition, by Haton de la Goupilliere, with revisions and addition by Jean Bes de Berg. Volume I. 1002 6½ × 10-in. pages; illustrated. Paper covers. Vve. Dunod. Paris. 1905. Complete in three volumes. Price, 90 francs.

Technological and Scientific Dictionary. Part X. Edited by G. F. Goodchild and C. F. Tweney. 64 7 × 10-in. pages. Paper covers. George Newnes. London. Price, one shilling. The work will be complete in 15 parts.

The Universal Directory of Railway Officials, 1905. Compiled under the direction of S. Richardson Blundstone, editor of the "Railway Engineer." 667 5½ × 8½-in. pages. The Directory Publishing Company. London. Price, 10 shillings.

Transactions of the Institution of Mining and Metallurgy. Volume XIII (1903–1904). Edited by Arthur C. Claudet and C. McDermid. 568 6×8½-in. pages; illustrated. Paper covers. E. and F. N. Spon. London.

Der Eisenbau, Luigi Vainello. 691 6 × 8½-in. pages; illustrated. R. Oldenbourg. Munich and Berlin. 1905. Price, 17.50 marks.

Technical Methods of Ore Analysis, by Albert H. Low. 273 6 × 9-in. pages; illustrated. John Wiley & Sons. New York. 1905. Price, $3.00.

Contribution a l'Étude de la Fragilité dans les Fers et les Aciers (Contribution to the Study of Brittleness in Iron and Steel). 482 9 × 11-in. pages; illustrated. Paper covers. Société d'Encouragement pour l'Industrie Nationale. Paris. 1904. Price, 20 francs.

Smithsonian Institution. Annual Report of the Board of Regents for the year ending June 30, 1904. 804 6 × 9-in. pages; illustrated. Government Printing Office. Washington, D. C. 1905.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

798,723. Malleableizing and Annealing Oven. — William L. Casaday, South Bend, Ind.

798,834. Pouring Device for Ladles, Etc. — Reinhold Schneider, Sharon, Pa.

799,001. Furnace for the Manufacture of Iron Sponge. — Gustaf Groendal, Djursholm, Sweden.

799,189. Producing Wrought-Iron Sponge. — Dexter Reynolds, Albany, N. Y.

799,269. Rolling-Mill Roll. — Ambrose Ridd, Newport, Ky., assignor of one half to Albert Simms, Newport, Ky.

799,542. Process of Cementing Iron or Steel. — Charles C. Davis, Germantown, Pa.

799,634. Production of Metallic Strip, Wire, Rods, Etc. — Sherard O. Cowper-Coles, London, England.

799,860. Process of Galvanizing Wire. — Guy L. Meaker, Evanston, Ill., assignor to the American Steel and Wire Company of New Jersey, a corporation of New Jersey.

799,861. Electrolytic Apparatus. — Guy L. Meaker, Evanston, Ill., assignor to the American Steel and Wire Company of New Jersey, a corporation of New Jersey.

799,862. Process of Separating Ferriferous Zinc Compounds. — Guy L. Meaker, Evanston, Ill., assignor to the American Steel and Wire Company of New Jersey, a corporation of New Jersey.

799,916. Feed-Train for Rolling Mills. — Emil Meyer, Duisburg, Germany.

800,018. Annealing Furnace. — Ambrose Ridd, Newport, Ky.

800,698. Preparing Fine Particles of Oxide of Iron for Use in Furnaces. — Utley Wedge, Ardmore, Pa.

800,712. Ingot Stripper. — John I. Blount, Donora, Pa., assignor to Whiting Foundry Equipment Company, Harvey, Ill., a corporation of Illinois.

800,857. Electric Furnace. — Fredrik A. Kjellin, Saltsjoebaden, Stockholm, Sweden.

GREAT BRITAIN

19,464 of 1904. Briquetting Ore. — C. Reinke, Bredelar, Germany. For briquetting fine iron ores, the use of a mixture of limestone containing

a high percentage of carbonate of lime, and Portland cement as binding material.

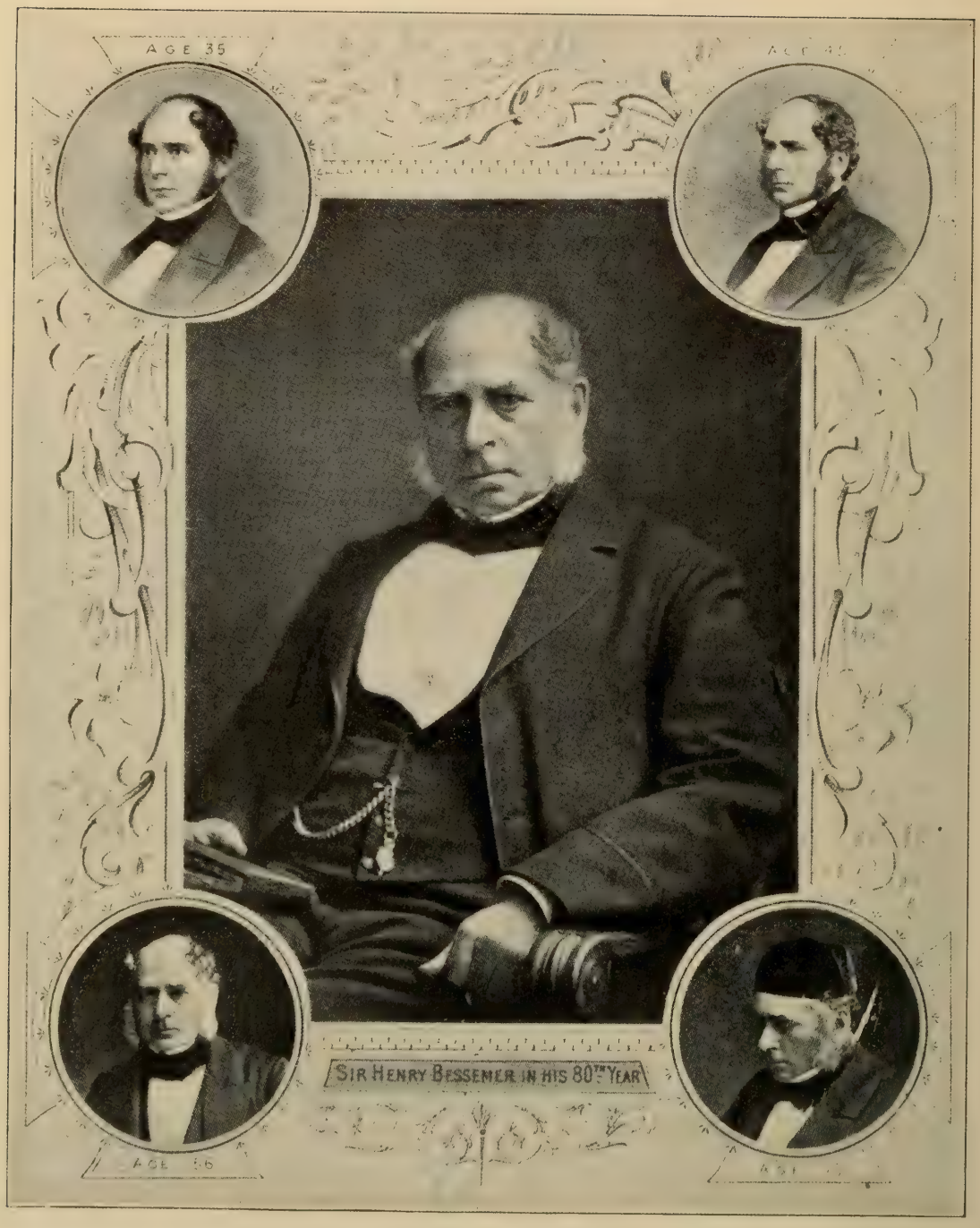
20,842 of 1904. GRATE-BAR ALLOY. — W. G. Crosthwaite, Leeds. An alloy of iron and aluminum for use in making firebars in furnaces, made by adding to 10 tons of pig iron, 2 cwts. of aluminum and 10 cwts. of scrap steel; will not burn away so quick as ordinary cast iron.

6,388 of 1905. BRIQUETTE FURNACE. — F. J. Bergendal, Herraeng, Sweden. An improved furnace for burning briquettes made of fine iron ores.

14,214 of 1905. ELECTRIC FURNACE. — F. A. Kjellin, Stockholm, Sweden. An improved method of arranging the electric fittings of electric furnaces, so that they do not get damaged by the heat of the furnace.

21,538 of 1904. DISPOSITION OF FLUE DUST. — A. Sahlin, London. Apparatus for removing dust from blast-furnace and similar gases, consisting of a revolving horizontal drum containing baffle-plates and water.

22,700 of 1904. BRIQUETTING MACHINE. — J. F. Pease, Darlington. Improvements in the mechanism of machines for making briquettes of iron ore, of the kind in which there are a succession of molds mounted on a circular frame and plungers to work into them.



SIR HENRY BESSEMER

The Iron and Steel Magazine

". . . . . Je veux au mond publier
d'une plume de fer sur un papier d'acier."

Vol. X December, 1905 No. 6

THE GENESIS OF THE BESSEMER PROCESS *

IT will, perhaps, assist the non-technical reader to understand what follows if I explain, in a few words, the forms in which iron and steel existed at the time when I commenced the experiments which resulted in the creation of the Bessemer process. At that date there was no steel suitable for structural purposes. Ships, bridges, railway rails, tires and axles were constructed of wrought iron, while the use of steel was confined to cutlery, tools, springs and the smaller parts of machinery. This steel was manufactured by heating bars of Swedish wrought iron for a period of some six weeks in contact with charcoal, during which period a part of the carbon was transferred to the iron. The bars were then broken into small pieces and melted in crucibles holding not more than sixty pounds each. The process was long and costly, and the maximum size of ingot which could be produced was determined by the number of crucibles a given works could deal with simultaneously. Such steel when rolled into bars was sold at £50 to £60 a ton. The wrought-iron bars from which the steel was made were manufactured from pig iron, as was all wrought iron, by the process known as "puddling." Naturally, such a process was costly; puddling demands great strength and endurance on the part of the workmen, combined with much skill.

Practically, all objects in iron, except such as were simply castings, were at that time made from wrought iron manufac-

* From Sir Henry Bessemer's recently published autobiography, through the courtesy of the publishers, "Engineering," London.

tured by puddling. The object I set before myself was to produce a metal having characteristics comparable with those of wrought iron or steel, and yet capable of being run into a mold or ingot in a fluid condition. I was aware that Fairbairn and others had sought to improve cast iron by the fusion of some malleable scrap, along with the pig iron, in the cupola furnace. This fusion of scrap iron, intermixed with a mass of coke, was found to convert the malleable iron into white cast iron, which was at the same time much contaminated with sulphur. Therefore, to a great extent, this system had failed in its object. In my experiments I avoided the difficulties inseparable from Fairbairn's method, by employing a reverberatory furnace in which the pig iron was fused. Into the bath so formed I put broken-up bars of blister steel, made from Swedish or other charcoal-iron, its fusion taking place without its being further carburized by contact with the solid fuel or contaminated by the absorption of sulphur. The high temperature necessary for the fusion of a large proportion of steel in the bath was obtained by constructing the fire grate much wider than the bath, by contracting the width of the furnace considerably at the bridge and also by continuing to taper slightly the furnace all the way from the fore bridge to the downcast flue, which was connected with a tall chimney shaft. Many alterations and modifications of this furnace were made from time to time, but it was found that the large volume of flame sweeping over the open hearth of the furnace was mixed with a considerable quantity of combustible gas. To consume this gas a hollow fire bridge was employed, having numerous perforations made in the clay lumps of which it was composed, and so arranged as to allow jets of hot atmospheric air to mingle with these combustible gases, and produce an intense heat close down to the surface of the bath. It was also found that this admission of hot air all along the back of the fire bridge produced a decarbonizing action on the bath; hence, the state of carburation of the metal might be altered by regulating the admission of air. This passage of air through the hollow fire bridge served also to keep down the temperature of the latter and render it more durable.

Some of the samples of metal which I produced were, when annealed, of an extremely fine grain and of great strength. At this stage of my experiments I cast a small model gun, which

in the lathe gave shavings slightly curled, and closely resembling the turnings from a steel ingot: the metal, when polished, also looked white and close-grained like steel. I was so well pleased with this little model gun that I took it over to Paris, obtained an audience with, and showed it to the emperor, who had encouraged this attempt to improve the iron employed in founding heavy ordnance. His Majesty, who had desired me to report progress, accepted this experimental gun, remarking that some day it might have an historical interest. It was in recognition of this circumstance that his Majesty, later on, intimated through Colonel Belleville, his desire to confer on me the decoration of the Legion of Honor, provided I could obtain permission to wear it, a privilege which our ambassador twice refused. His Majesty also sanctioned the erection of my furnace at the Government Cannon Foundry at Ruelle, near Angoulême, to which place I went with proper introductions for the purpose of arranging all the necessary details. I also sent over from England several thousand special fire bricks, etc., for the erection of the furnaces.

But, on resuming my further researches, after my return to London, an incident occurred which suddenly put a stop to the intended works at the Ruelle gun foundry, and in fact altered all my future plans and investigations.

The furnace, as then arranged, is shown in vertical section in Fig. 35, and in horizontal section, on the line passing above the fire bridge, in Fig. 36, Plate XII, the bath being empty and showing the tapping hole and the way in which the furnace narrows at the fire bridge. Fig. 37, on the same plate, is also a horizontal section, taken on a line passing through the openings in the perforated hollow fire bridge, and clearly shows how the jets of air were directed so as to produce an intense ignition of the combustible gases, mingled with, and passing over with, the large volume of flame from the overcharged fire grate.

The small scale on which this experimental furnace was built (a capacity of 3 cwt. only) was much against my obtaining the high temperature necessary to melt a large proportion of steel in a pig-iron bath. I was, of course, fully aware that a furnace of sufficient capacity to cast a 5-ton or a 10-ton gun would acquire a much higher temperature than was possible in my small furnace. I knew, also, that forced draft obtained by

PLATE XII.

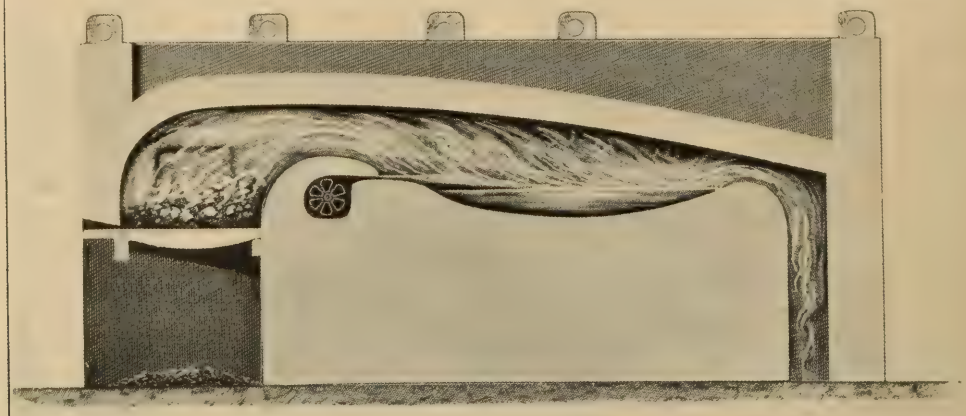


FIG. 35. VERTICAL SECTION OF FURNACE FOR MAKING MALLEABLE IRON

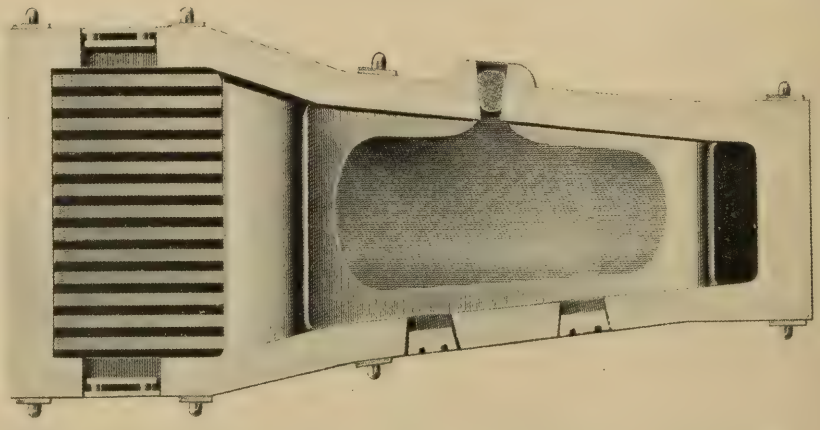


FIG. 36. HORIZONTAL SECTION OF FURNACE FOR MAKING MALLEABLE IRON

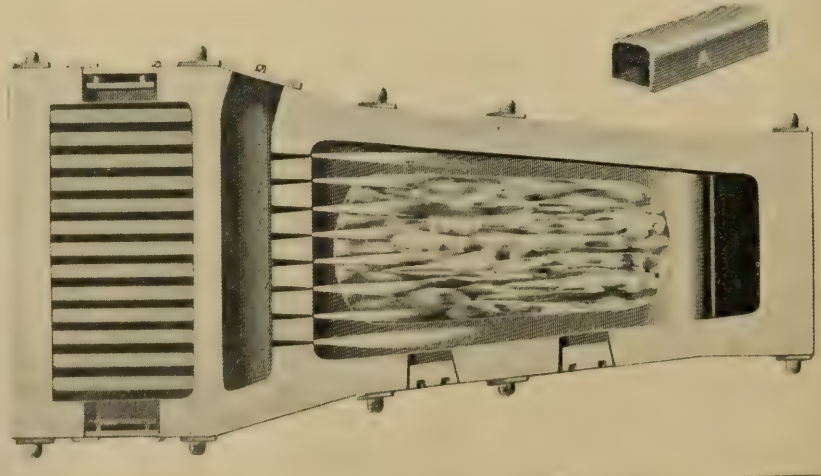


FIG. 37. Horizontal Section of Furnace for Making Malleable Iron

closing in the ash pit and forcing air into it would still further increase the temperature. That this forced draft was in my mind at the time is shown by the fact that I took out a patent for the manufacture of cast steel, dated October 17, 1885; that is, about two months after the casting of the model gun, in which specification I fully described the forcing of air by a fan into the closed ash pits of the furnaces employed in the manufacture of cast steel. It has since often occurred to me that, with these additional resources still untried, I did not act wisely in so suddenly abandoning these open-hearth experiments, in favor of an entirely different system, suggested to my mind by the incident to be presently referred to. But with my impulsive nature, and intense desire to follow up every new problem that presented itself, I at once threw myself unreservedly into this new study, which seemed to open the way to the rapid production of bars, rails and plates of malleable metal direct from the blast furnace.

Before dismissing this subject, it may be interesting, even at this distant period, to speculate on what would have been the natural outcome of my open-hearth furnace experiments, had I not been so suddenly diverted from their further pursuit.

Such a furnace, with forced draft and a capacity of ten tons, would undoubtedly have melted malleable iron or steel in a bath of pig iron, and have decarburized the latter to the desired extent; for I had, in fact, already fused steel in a bath of pig iron on the open hearth of this small reverberatory furnace, and as far back as January, 1855, I had claimed in my patent: "*The fusion of steel in a bath of melted pig or cast iron in a reverberatory furnace, as herein described.*"

This was about ten years prior to the patent taken out by M. Emile Martin, and now generally known as the "Siemens-Martin process." This latter patent was obtained in England in the name of A. Brooman, the patent agent of Emile Martin, and is dated August 18, 1865, or more than ten years after my patent of January 10, 1855. M. Emile Martin in his patent says: "*The manufacture is effected upon the principle of fusion of iron or natural steel in a bath of cast iron, maintained at a white heat in a reverberatory furnace, such as Siemens gas furnace.*"

I, however, desire to say that I make no claim to the prior invention of the Siemens-Martin process, nor do I assume that my patent of 1855 furnished any information which either of

these gentlemen had availed themselves of, although my patent for melting steel in a bath of cast iron on the hearth of a reverberatory furnace had been granted, and the specification published, some nine years prior to M. Martin's application for his patent. But seeing how many years I was in advance of M. Martin, I feel perfectly justified in saying that the fusion of steel in a bath of pig iron on the open hearth of a reverberatory furnace, which I had patented and accomplished ten years prior to the Siemens-Martin patent, was, to use a favorite expression of Mr. Gladstone, "approaching within measurable distance" of that successful process known as the open-hearth manufacture of mild steel.

On my return from the Ruelle gun foundry I resumed my experiments with the open-hearth furnace when the remarkable incident mentioned above occurred in this way. Some pieces of pig iron on one side of the bath attracted my attention by remaining unmelted in the great heat of the furnace, and I turned on a little more air through the fire bridge with the intention of increasing the combustion. On again opening the furnace door, after an interval of half an hour, these two pieces of pig still remained unfused. I then took an iron bar, with the intention of pushing them into the bath, when I discovered that they were merely thin shells of decarburized iron, as represented at A, Fig. 37, Plate XII, showing that atmospheric air alone was capable of wholly decarburizing gray pig iron, and converting it into malleable iron without puddling or any other manipulation. Thus a new direction was given to my thoughts, and after due deliberation I became convinced that if air could be brought into contact with a sufficiently extensive surface of molten crude iron, it would rapidly convert it into malleable iron. This, like all new problems, had a special interest for me, and I became impatient to test it by a laboratory experiment. Without loss of time I had some fire-clay crucibles made with dome-shaped perforated covers, and also with some fire-clay blow pipes, which I joined on to a 3-foot length of 1-inch gas pipe, the opposite end of which was attached by a piece of rubber tubing to a fixed blast pipe. This elastic connection permitted of the blow pipe being easily introduced into and withdrawn from the crucible, as shown at Fig. 38, Plate XIII, which represents a vertical section of an air furnace containing a crucible that, in this case,

forms the "converter." About ten pounds of molten gray pig iron half filled the crucible, and thirty minutes' blowing was found to convert 10 pounds of gray pig into soft malleable iron. Here at least one great fact was demonstrated, viz., the absolute decarburization of molten crude iron without any manipulation, *but not without fuel*, for had not a very high temperature been kept up in the air furnace all the time this quiet blowing for thirty minutes was going on, it would have resulted in the solidification of the metal in the crucible long before complete decarburization had been effected. Hence arose the all-important question: Can sufficient internal heat be produced by the introduction of atmospheric air to retain the fluidity of the metal until it is wholly decarburized in a vessel not externally heated? This I determined to try without delay, and I fitted up a larger blast cylinder in connection with a 20 horse-power engine which I had daily at work. I also erected an ordinary founder's cupola, capable of melting half a ton of pig iron. Then came the question of the best form and size for the experimental "converter." I had very little data to guide me in this, as the crucible converter was hidden from view in the furnace during the blow. I found, however, that slag was produced during the process and escaped through the holes to the lid. Owing to this, I determined on constructing a very simple form of cylindrical converter, about four feet in height in the interior, which was sufficiently tall and capacious, as I believed, to prevent anything but a few sparks and heated gases from escaping through a central hole made in the flat top of the vessel for that purpose, as shown in the vertical section at Fig. 39, Plate XIII. The converter had six horizontal tuyères arranged around the lower part of it; these were connected by six adjustable branch pipes, deriving their supply of air from an annular rectangular chamber, extending around the converter, as shown.

All being thus arranged, and a blast of 10 or 15 pounds pressure turned on, about 7 cwt. of molten pig iron was run into the hopper provided on one side of the converter for that purpose. All went on quietly for about ten minutes; sparks such as are commonly seen when tapping a cupola, accompanied by hot gases, ascended through the opening on the top of the converter, just as I supposed would be the case. But soon after a rapid change took place; in fact, the silicon had been quietly consumed, and

PLATE XIII

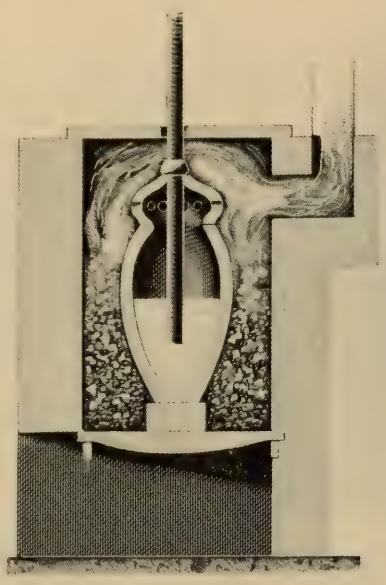


Fig. 38. Section of Crucible with Blow Pipe

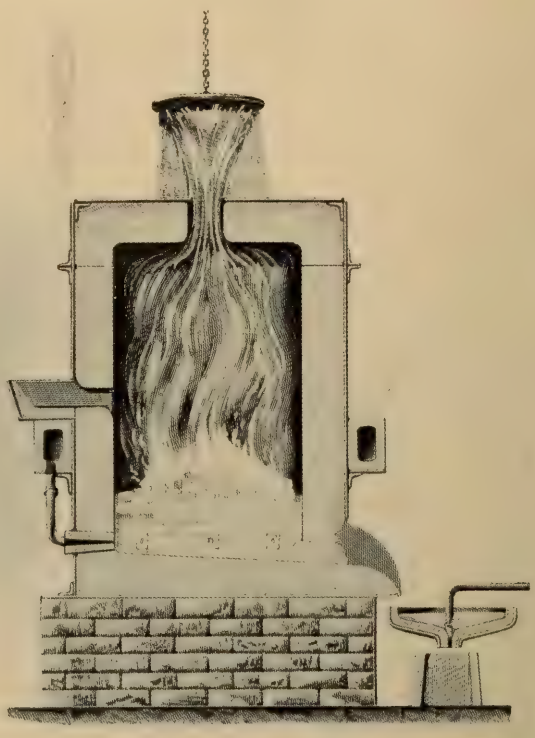


Fig. 39. Section of Vertical Converter

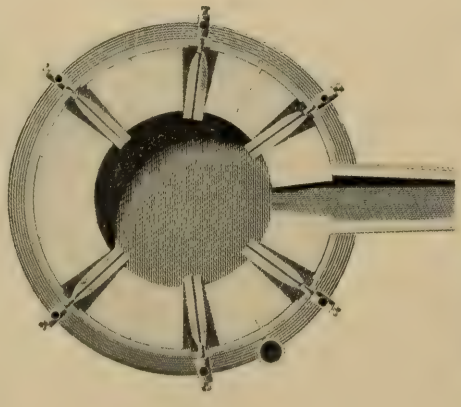


Fig. 41.

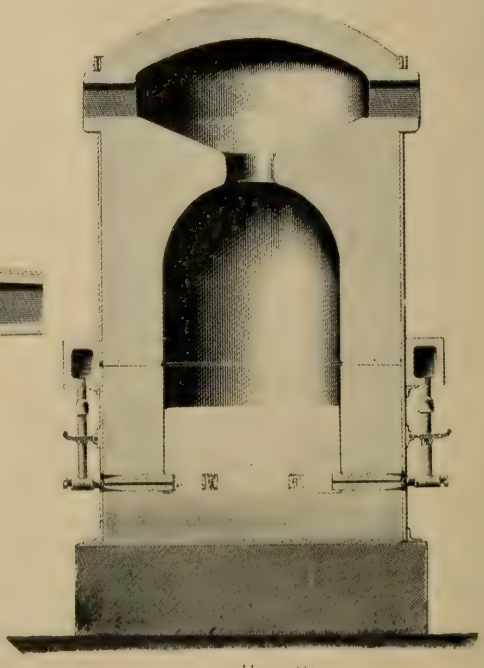


Fig. 40.

Figs. 40 and 41. Sections of Vertical Converter with Upper Chamber

the oxygen, next uniting with the carbon, sent up an ever-increasing stream of sparks and a voluminous white flame. Then followed a succession of mild explosions, throwing molten slags and splashes of metal high up into the air, the apparatus becoming a veritable volcano in a state of active eruption. No one could approach the converter to turn off the blast, and some low, flat, zinc-covered roofs, close at hand were in danger of being set on fire by the shower of red-hot matter falling on them. All this was a revelation to me, as I had in no way anticipated such violent results. However, in ten minutes more the eruption had ceased, the flame died down and the process was complete. On tapping the converter into a shallow pan or ladle, and forming the metal into an ingot, it was found to be wholly decarburized malleable iron.

Such were the conditions under which the first charge of pig iron was converted in a vessel neither internally nor externally heated by fire.

I, however, desired to convert a second charge of pig iron which had been put into the cupola; and in order to prevent this dangerous projection upwards of sparks and molten slags, a temporary expedient was resorted to, which, however, failed in its object.

I procured one of those circular, checkered cast-iron plates so much used in the London pavements to allow coals to be put in the cellars below the pavement. This plate which was about a foot in diameter, was suspended by a chain at a distance of about 18 inches above the central opening in the top of the converter, as shown in Fig. 39, Plate XIII.

This, as a mere temporary device, was deemed sufficient to allow the conversion of another 7 cwt. charge to be effected without any danger of setting fire to the premises. The converting operation went on quietly as before, but when the eruption commenced, I saw the suspended plate get rapidly red hot, and in a few minutes more it melted and fell away, leaving the chain dangling over the opening, and allowing the slags and splashes of metal to shoot upwards as before. Thus it happened that the first converter that I constructed was at once condemned as commercially impracticable, owing to this vertical eruption of cinder, and for this reason only.

All attempts to lessen the violence of the process by the

reduction of the number of tuyères, or by lessening their diameter, or by diminishing the pressure of the blast, only resulted in a reduction of the necessary temperature, and in preventing the conversion of the molten pig into malleable iron. In one case the trial of a diminished area of tuyère openings resulted in nearly the whole charge of metal, after more than an hour's blowing, being converted into a solid mass of brittle white iron, similar to ordinary refiner's plate metal. Indeed, I may say the result of all my early investigations proved to me, beyond the possibility of a doubt, a fact which has since been confirmed in every Bessemer steel works throughout Europe and America, viz., that rapidity of action, ending in a violent eruption, is an absolutely necessary condition of success. Not only must the converted metal acquire an enormously high temperature, so that it may not be chilled when pouring it out of the converter, or when a relatively large quantity of much cooler metal be added to deoxidize it, but it must not chill and form a shell in the ladle during the comparatively long time required for casting the ingots. Hence, to carry out the Bessemer process successfully, a temperature must be obtained very considerably above the mere melting temperature of malleable iron; and in order to secure this it is necessary to drive powerful streams of air into the metal, so as to divide it into innumerable tiny globules diffused throughout the whole body of iron under treatment which, for the time being, may be likened to a fluid sponge with the active combustion of carbon with oxygen going on in every one of its myriads of ever-changing cavities.

It has been found that the union of carbon and oxygen takes place so rapidly at this high temperature as to produce a series of mild explosions. In the large converters in common use, a space some 8 feet or 10 feet in height above the normal level of the metal is provided, in which this violent action expends itself unseen, and is only partially recognized by a small quantity of slags leaping out of the mouth of the converter.

With these facts before us, it must be self evident that all attempts to produce malleable iron in a plain cylindrical vessel that has no top to it, and in which the metal normally rises to within 6 inches of the open mouth, must utterly fail from two causes: first, because heat would fly off so freely that the temperature of molten malleable iron could never be reached; and secondly,

because nearly all the metal contained in such a shallow, open-topped vessel would have leaped out of it, and have been scattered in all directions on the occurrence of the explosive eruption, without which no charge of molten pig iron has, or can be, converted into fluid malleable iron by a blast of air.

I had no sooner condemned my first cylindrical converter than I commenced to remedy its defects. The most obvious and ready way of doing this would have been simply to make an opening on one side of it near the top, and thus allow the escape of the ejected matter to take place horizontally, directing it against a wall, or allowing it to fall into a pit. But I desired to prevent this discharge of metal splashes as much as possible. Hence I determined on constructing a new converter with an upper chamber, having an arched roof and a conical sloping floor. This converter is represented in Figs. 40 and 41, on Plate XIII, the last-named view being a horizontal section through the tuyères. When a converter is so constructed, the ejected fluid that would otherwise pass vertically upwards into the air is thrown against the arched roof, and any metal that may be emitted falls again on the sloping floor of the upper chamber and returns to the lower one. The flame and a portion of the slags find their way out of the two square lateral openings provided for that purpose. This upper chamber also served as a receptacle for heating up any metal intended to recarburize, or alloy with, the steel in course of being converted. The sectional plan, Fig. 41, shows six well-burned fire-clay or plumbago tuyère pipes fitted to openings left in the lining for that purpose. Their outer ends were made conical to facilitate the ramming in of loam around them, which effectually held them in position, and at the same time admitted of their easy removal when worn out; a jointed piece of iron tube, with a catch to hold it in place, conveyed the blast to each tuyère.

Another view, Fig. 42, Plate XIV, of this converter, taken at right angles to Fig. 40, shows on one side the hopper by which the molten iron was run into it by a movable spout direct from the cupola. This view also shows the tapping-hole open, and the spout which conducted the converted metal into a movable shallow pan or receiver, supported by a long handle (not shown). A fire-brick plug attached to a long handle was fitted to a fire-brick ring or opening in the bottom of the pan, and prevented

PLATE XIV

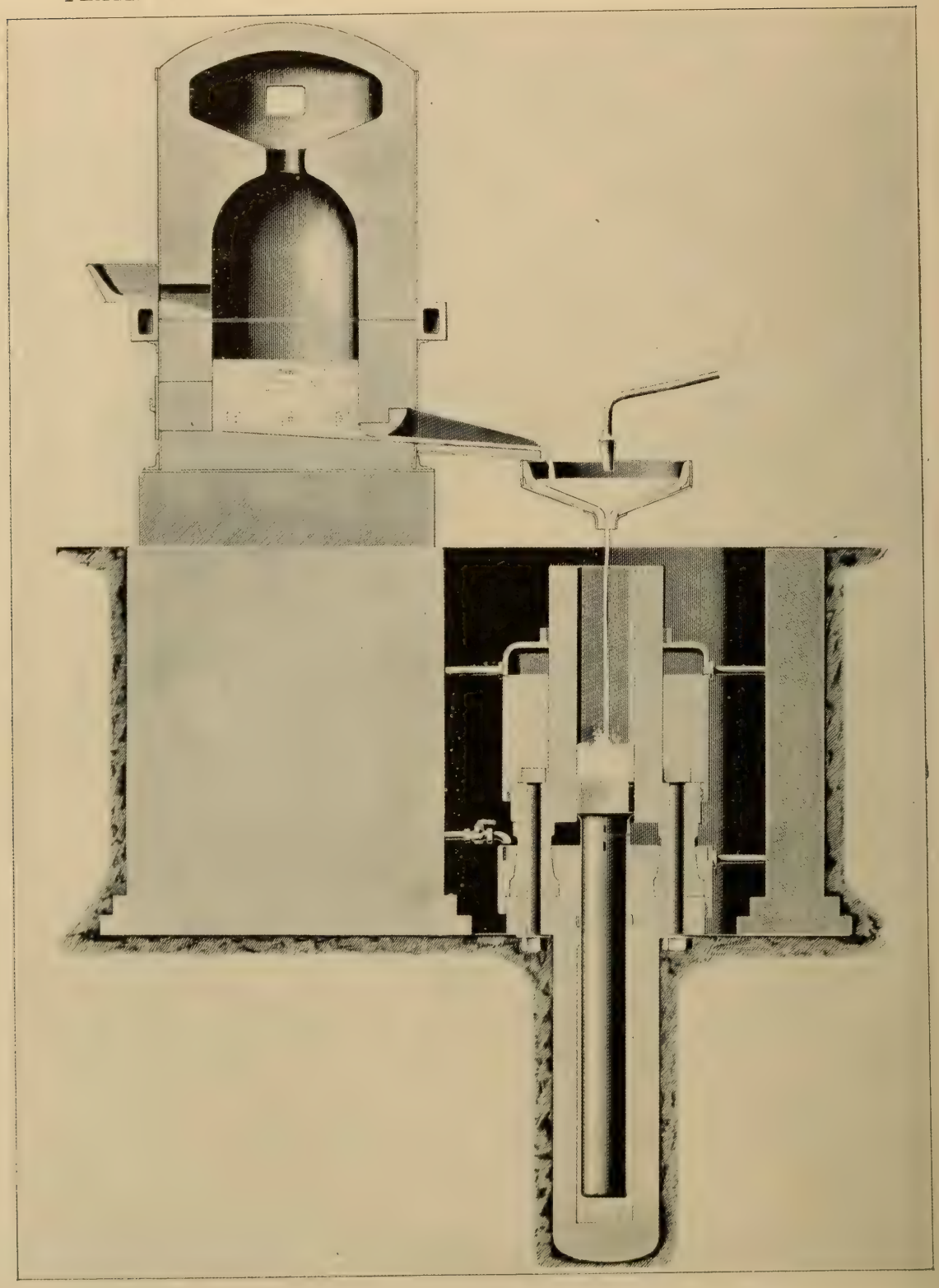


FIG. 42. Section of Converter, Ladle and Hydraulic Ingot Mold

any *débris* from the tapping hole being carried into the mold. As this apparatus was intended to exhibit the process, it was essential that an easy way should be provided for getting away the ingots and quickly repeating the operation. This casting apparatus, constructed precisely as represented in Fig. 42, was erected at my Bronze Manufactory in London, about two months prior to my reading the "Cheltenham" paper, in August, 1856, to which I shall refer later. The mold was 10 inches square, and about 3 feet in length inside; it was made in two pieces planed quite parallel, and then permanently bolted together. The base was a massive square flange, resting on four dwarf columns, which stood on the square upper flange of an hydraulic cylinder; bolts passed through these dwarf columns, and through the square flanges, thus uniting the ingot mold and hydraulic cylinder. To the latter a ram or plunger was fitted, having a movable square head, which accurately fitted the mold, and formed a movable bottom to it. Both the ram and the external surface of the mold were kept cool by a water jacket, provided with supply and waste pipes. Matters being thus arranged, the converted metal was allowed to fall in a vertical stream from the receiver on to the head of the ram. The receiver was then removed and as soon as the steel was solidified, water under pressure was turned on to the hydraulic cylinder, when a beautiful ingot, 10 inches square and weighing about 7 cwt., steadily rose and stood on end ready for removal, the head of the ram rising one or two inches above the top of the mold. There are, no doubt, many persons still living who witnessed this combined converting and casting apparatus in successful operation.

Two 10-inches square ingots, made with this apparatus, were sent to the Dowlais Iron Works in Wales, and, without hammering, were rolled into two flat-footed rails on the 6th of September, 1856; that is, twenty-four days after the reading of the "Cheltenham" paper. They were rolled under the personal superintendence of Mr. Edward Williams, past president of the Iron and Steel Institute. Two pieces of these rails are still kept at the Institute in a large glass case containing many other examples of the early working of my process in London and in Sheffield.

Before concluding this brief sketch of the earliest forms of apparatus designed by me to facilitate or improve the process,

PLATE XV

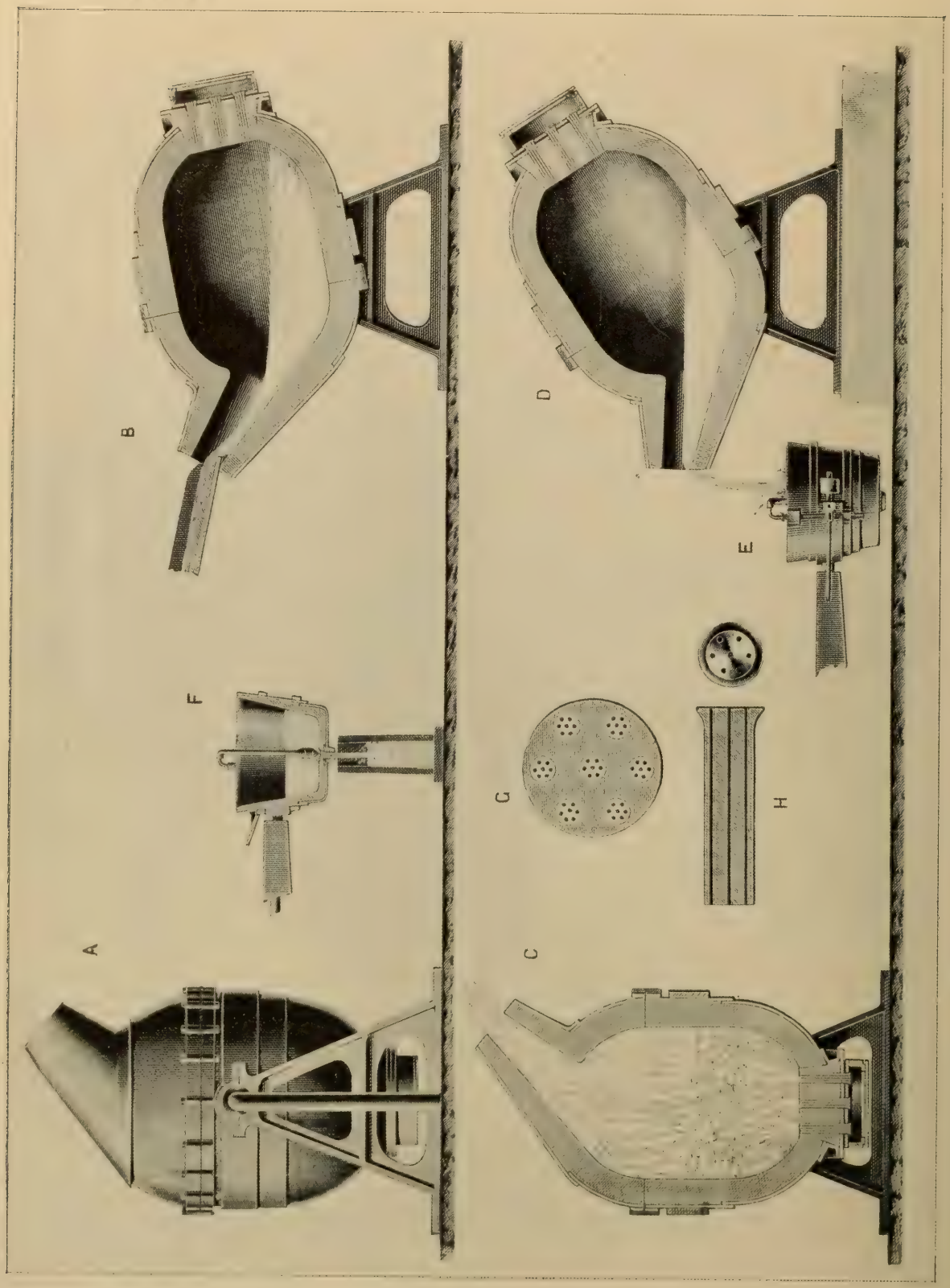


FIG. 43. The First Form of Bessemer Movable Converter and Ladle

I must revert to the difficulties inseparable from a fixed converter. In this form of apparatus much heat is dissipated by the blowing which takes place during the running in of the metal and by the continuation of the blast after the metal is converted and during the whole time of its discharge, which is a period of uncertain length. There is also the difficulty of stopping the process if anything goes wrong with the blast engine, or if a tuyère gives way. I searched diligently for a remedy for these and other grave defects, which at that time appeared impossible to remove, until the happy idea occurred to me of mounting the converter on axis, so as to be able to keep the tuyères above the metal until the charge of molten iron was run in, thus permitting the blowing of the whole charge to be commenced at one and the same time, and admitting also of the cessation of blowing during the discharge. This movement of the converter permitted a stoppage of the process to take place at any time for the removal of a damaged tuyère, if necessary, and afforded great facilities for working.

The special form of the movable converter was also a matter of great importance, and there were several requirements to provide for. First, in order to make the heavy lining secure when turned upside down, a more or less arched shape in all directions was necessary. A long oval form seemed best adapted to the purpose, as it allowed some eight or nine feet in height for the metal to throw itself about in without leaving the converter. Then the large mouth or outlet pointing to one side was desirable, so that the sparks could be discharged away from the casting pit. After much study I arrived at the form shown at A, Fig. 43, Plate XV, which is an external elevation; B is a vertical section showing the position in which the vessel is retained during the running in of the metal; C shows it during the blow, and D the position it assumes when the converted metal is poured into a loamed-up casting ladle. This ladle is shown at E and F; it is provided with a discharge valve at the bottom, so that it can be moved from mold to mold by closing the valve during such movement, and then permit a vertical stream to descend into the mold perfectly free from any mixture of slags. The advantage of this mode of filling the molds will be understood when it is borne in mind that they are necessarily narrow unright vessels. It is well known that a stream of molten metal poured from the

PLATE XVI

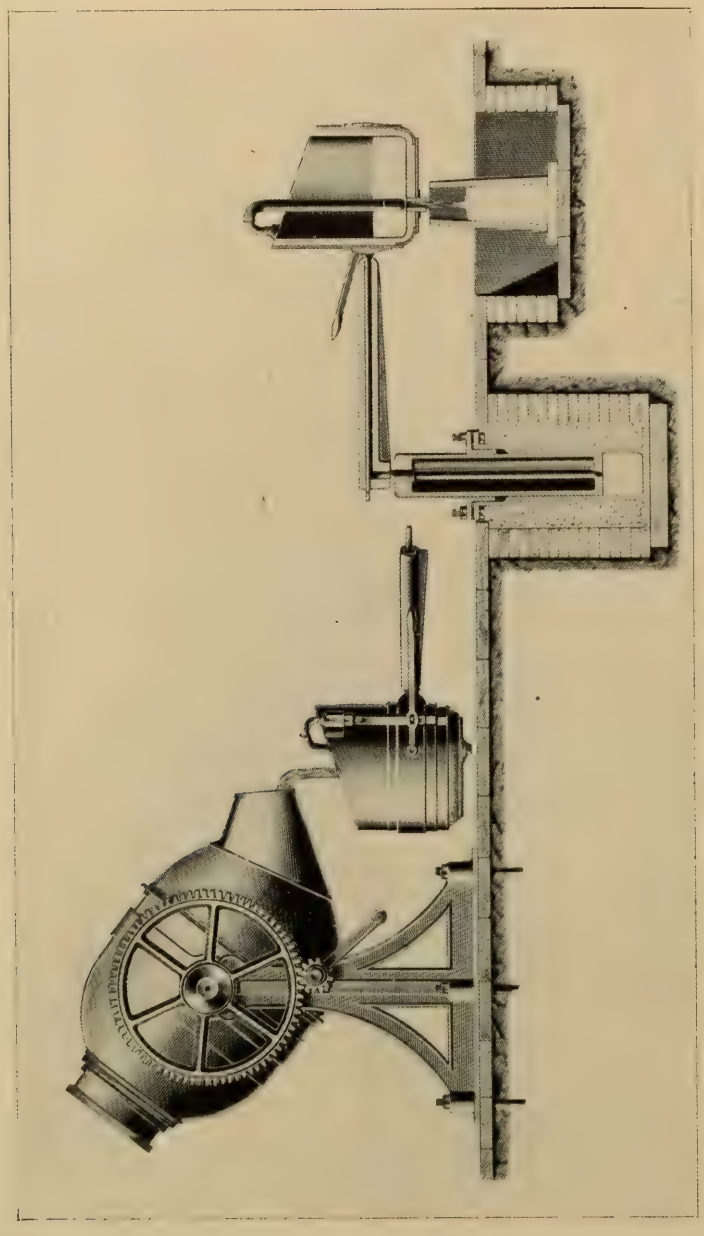


FIG. 44. Early Form of Bessemer Converting Plant at Sheffield

PLATE XVII

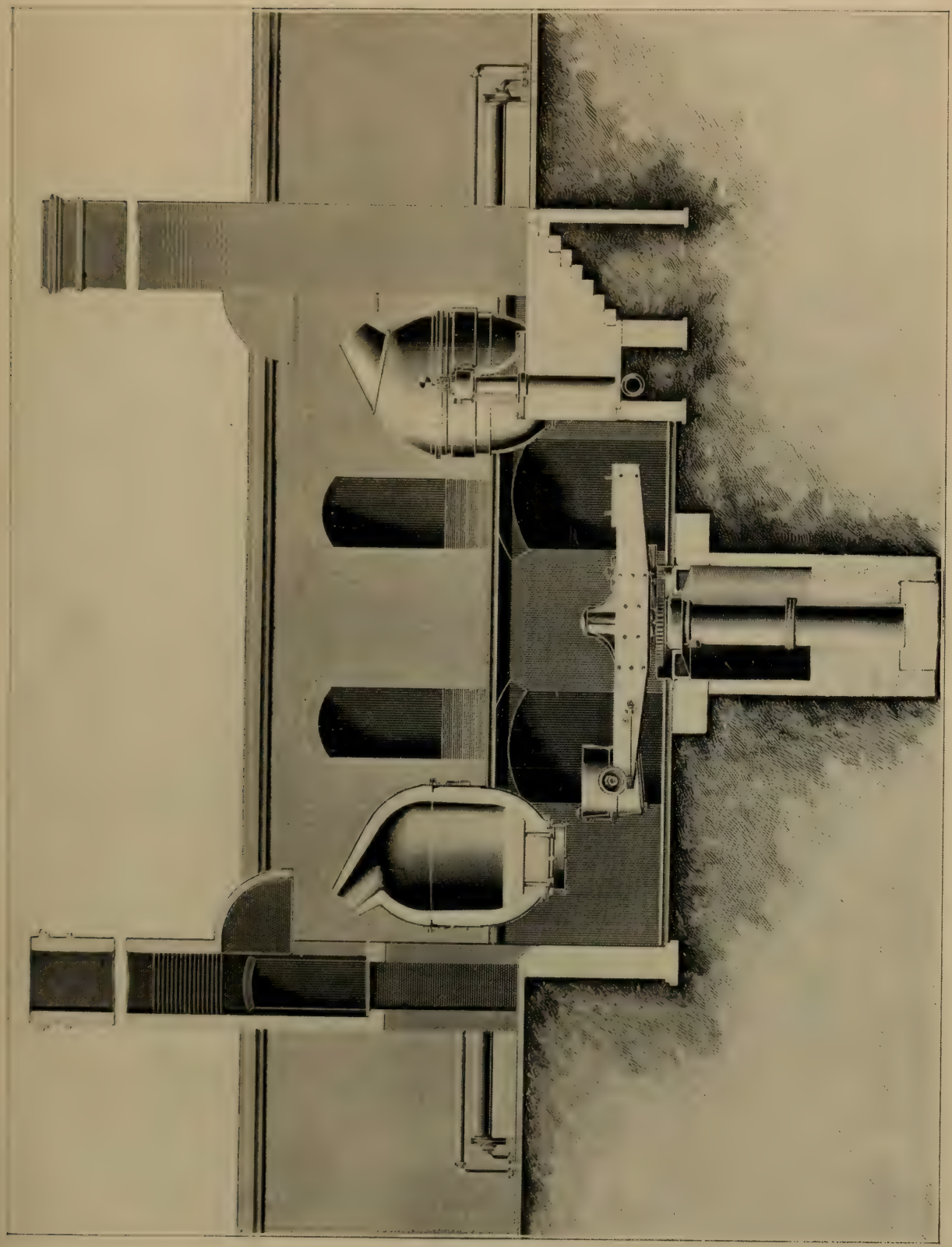


FIG. 45. Bessemer Plant at Sheffield: Converters, Ladle and Crane and Casting Pit

lip of a ladle will describe a parabolic curve in its descent, tending to strike the further side of the mold before reaching the bottom. The surface of the cast-iron mold so struck is instantly melted by the incandescent stream of steel, and the ingot and the mold thus become united, causing great inconvenience. Nor is it easy, in pouring the steel from the lip of the open ladle, to prevent some of the fluid slag floating on its surface from flowing over with the steel and spoiling the ingot. All of these difficulties are avoided by the ladle fitted with a bottom valve discharging a vertical stream down the center of the mold, the quantity and flow being regulated with great facility by the hand-lever on the side of the ladle. At G and H, Fig. 43, are shown the bottom of the converter and the form of tuyères.

Many other mechanical contrivances were necessary to perfect the process, such, for instance, as my patent blast engine, with its noiseless self-acting valve; the hydraulic crane carrying the pouring ladle over every mold in the semi-circular casting pit, and designed to rise and fall in accordance with the movement of the converter when filling the ladle for casting; the direct-acting ingot cranes, which clear the pit and refill it with another set of molds rapidly, and with very little manual labor; the elevated "valve-stand," from which safe position a single workman can overlook the whole converting apparatus, and control all their movements, govern the blast and work the hydraulic cranes, etc.

The mode of transmitting semi-rotating motion to the converter was another important problem which I had to solve. I was of opinion that ordinary shafting and straps were inapplicable to this fiery monster. Five or ten tons of fluid metal had to be lifted in one direction, this load diminishing until the fluid running to the opposite end of the converter tended to reverse the driving gear. If anything went wrong, or slipped, the converter might swing itself round and discharge the incandescent metal on to the floor or among the workpeople. These considerations led me to adopt the hydraulic apparatus now universally employed for governing the motions of the converter: for, with this simple and reliable means, a lad at a safe distance can start or stop it instantly, can alter its speed and motion and control the pouring of a 10-ton charge with ease and certainty.

The first movable converter was erected at my steel works

PLATE XVIII

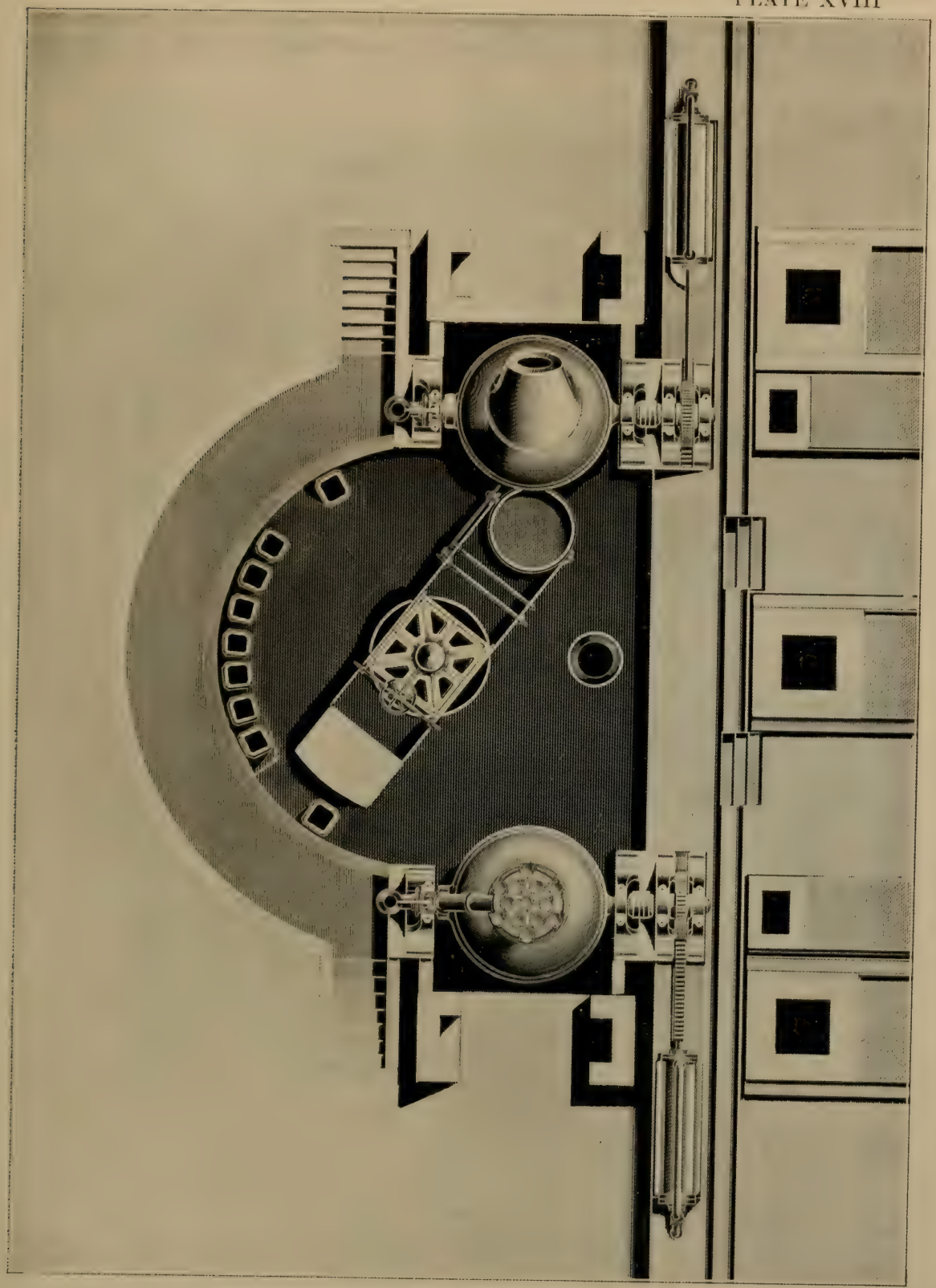


FIG. 46. Plan of Bessemer Plant at Sheffield

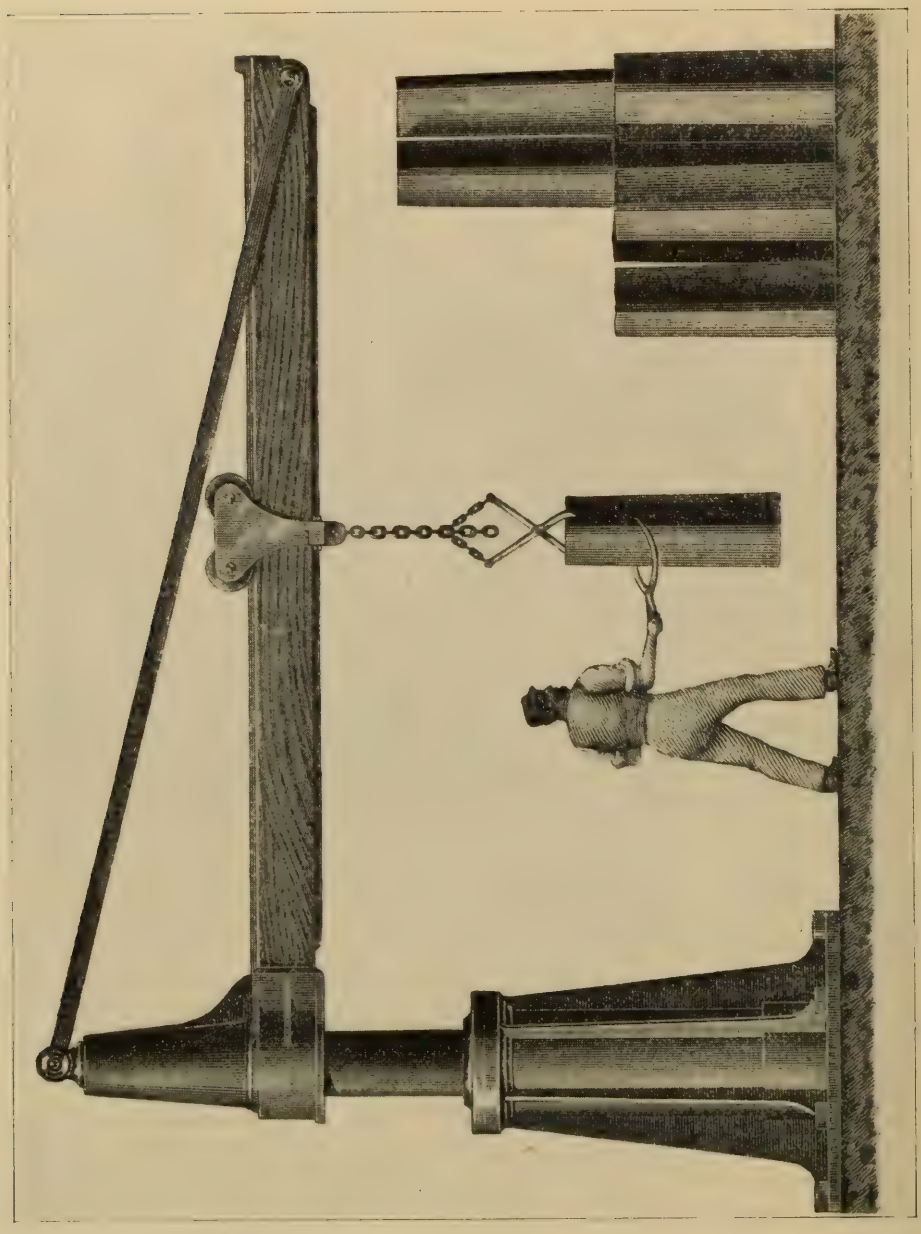


FIG. 47. Ingot Crane; Bessemer Plant at Sheffield

at Sheffield and was moved by hand gearing, because at that early date I had not invented the hydraulic apparatus just described. This early converting plant did good work at Sheffield, and was constructed precisely as represented in Fig. 44, Plate XVI, which shows also the first modification of the hydraulic casting crane, and its ladle with valve, afterwards elaborated by me and rendered suitable for casting heavy charges of steel. The development of this earliest form of plant is shown in Figs. 45 and 46, Plates XVII and XVIII, and Fig. 47, annexed. The early experiments at Baxter House were so far successful as to justify myself and some of my friends in entering into partnership and erecting in the town of Sheffield, a steel works which still remains in active operation under the style of "Henry Bessemer & Company, Limited." These works were established both for commercial purposes and also to serve as a pioneer works or school, where the process was for several years exhibited to any iron or steel manufacturers who desired to take a license to work under my patents. All of these were allowed, either personally or by their managers, to see their own iron converted prior to their taking a license.

DRY AIR FOR BLAST FURNACES*

IN the report in "The Iron Age" of July 27, 1905, pages 214–216, of the proceedings of the Congress of Mining and Metallurgy, held in connection with the International Exhibition at Liége, Belgium, a synopsis was given of the papers read and the accompanying discussions. Several papers among those read by title have not been published. From advance proofs of these, furnished through the courtesy of the secretary of the Metallurgical Section, Constant Renson, technical manager of the Angleur Iron and Steel Works, near Liége, the following abstracts have been prepared:

Effect of Dry Blast on Furnace Working

A. LODIN

The increase of 25 per cent in output, with a saving of 20 per cent in coke consumption through drying the blast, announced by Mr. Gayley at the New York meeting of the Iron and Steel Institute last year, attracted much attention from metallurgists. These results were obtained at the Isabella furnaces, near Pittsburg, with a plant put up in accordance with Mr. Gayley's last patent. Notwithstanding several obscure points which were not cleared up in Mr. Gayley's paper at the last May meeting of the Iron and Steel Institute, his communication possesses great interest, owing to the practical results obtained. The author considers that the only reactions susceptible of being influenced by humidity in the blast were reduction of the silicon and manganese, with fusion of the pig and slag. The water vapor introduced into the space above the tuyères reacts immediately upon the coke, while forming carbonic acid and absorbing 3,220 calories per kilogram, or 5,976 British thermal units per pound of coke burned. As the proportion introduced by the blast increases, the mean temperature of the space above the tuyères diminishes, the reduction of the silicon first becomes less active and the pig has a tendency to pass from gray to white. Then, on the temperature becoming still lower, the charges cease to melt above the tuyères, so that

* Papers presented at the Liége Mining and Metallurgical Congress, abstracted in "The Iron Age," November 16, 1905.

a scaffold forms. All absorption of heat occurring in the region of the tuyères, like that due to decomposition of the humidity in the blast, will delay the descent of the charges and diminish the production in a ratio corresponding with the variation, not of the total quantity of heat disengaged above the tuyères, but of the combustion temperature of the carbon when the normal working is established.

If it be desired to maintain the output notwithstanding this disturbing influence, a quantity of heat equal to that abstracted must be returned to the zone of the tuyères. Formerly this could only be effected by burning an additional volume of carbon, but heating the blast has afforded a far more effective method of compensation, for it gives an exact counterpart of the action exerted by the water vapor. The additional heat introduced by the blast is utilized entirely by the fusion, and its relative effect is so much the more considerable as the combustion temperature of the carbon above the tuyères was originally lower, or as the working of the furnace must be kept hotter.

It is impossible under the conditions described by Mr. Gayley to regard the drying of the blast as the main cause of the saving effected. It must contribute to reduce the coke consumption, but if the part played by the absorption of heat corresponding with the decomposition of the water in the blast becomes reduced to almost nothing (as in one of the cases considered) another cause must be sought for difference in the fuel consumption. The principal cause must be an influence acting with constant intensity during the whole experimental period.

The diminution of one tenth the weight of blast passing through the tuyères during a given time is of a nature to exert great influence on the working of the furnace. If the previous working were too rapid it might be improved by a reduction of the blast, which would prevent the ore from attaining the space above the tuyères in a state of incomplete reduction, so as to become scarified there, while forming silicates that can only be reduced by the action of solid carbon, with the formation of carbonic oxide and considerable absorption of heat. If the descent of the charges should slacken, the reduction by the gaseous current would be effected more completely, the coke consumption would diminish and the composition of the furnace

gases would be modified to advantage by increase in the ratio of CO_2 to CO.

It may be asked if the relative acceleration of working at the Isabella furnaces was not obtained at the expense of fuel economy, and if the improvement attributed by Mr. Gayley to drying the blast is not chiefly due, during the winter period at any rate, to reduction in the quantity of blast introduced in a given length of time. For clearing up this question only one of the factors capable of modifying the furnace working must be varied at a time; and the experiments in this direction should by preference be made on blast furnaces in normal working. Everything leads to the belief that drying the blast would only exert a subsidiary advantage if applied to furnaces blown with a very hot blast and so arranged that the ore arrives in a reduced state at the space above the tuyères.

The Blast-Drying Problem

VICTOR DEFAYS

It follows from the various communications made to the congress on this subject that (1) drying the blast undoubtedly reduces the coke consumption and increases the output; (2) there is contraction in Mr. Gayley's figures given at the New York meeting of the Iron and Steel Institute, and not only so, but (3) certain elements of appreciation are so far wanting that the practical results cannot be verified by calculation; (4) M. Divary's information (from experiments at Creusot, summarized on page 404 of " The Iron Age " of August 17, 1905) as to the influence of humid air on the working of his furnaces has great interest because concording with Mr. Gayley's results, while also affording metallurgists a valuable method of investigation, and (5) the proposed remedy will probably exert a different effect according to local circumstances.

Considering that the question is of far greater importance than is generally supposed, and thoroughly appreciating the adage that for working well a blast furnace must have the feet warm and the head cool, the author concludes: (1) A trial of the Gayley system in any given blast furnace can only have value for furnaces under the same conditions. (2) It is advisable to select twenty furnaces working under the most different

conditions possible and on which the Creusot observations should be made for a given period, which would permit of determining far more certainly and with less expense than by a simple trial the chances of advantage which metallurgists may derive from drying the blast.

A furnace manager has no greater enemy than the steam introduced at the base of his furnace. If a tuyère should leak and not at once be attended to, the bottom of the furnace will cool down and fire reach the mouth. What occurs on a large scale in such an accident is always going on to a certain extent, owing to the water vapor with which the blast is charged. In fact, the water acts as a vehicle of heat units, which it conveys from the bottom to the top of the furnace. As it appears well established that the constant increase in the temperature of the blast and the height of the furnace is chiefly for counteracting the water vapor in the air, it may be asked whether on almost entirely suppressing the cause there is not reason to return, to some extent at least, to former practice? If the experiment be successful it would naturally follow that very high temperatures of blast must be abandoned and the profile of the furnace must be remodeled, especially its height reduced.

Lower Blast Temperature

As regards reducing the blast temperature, the problem of coke economy assumes a very different aspect now that waste gases are utilized. The saving may take the form of one in physical heat — that of the gas taken off from the mouth, a radical loss, should be especially avoided, and all the more as it complicates the purification of the gas — or there may be an economy in the quantity of gas and its value in chemical heat (improving in the ratio of CO_2 to CO). If, thanks to drying the blast, less gas be required to heat it, more will be left for other purposes. And this diminution in heating the blast will have another consequence, viz., that the stoves will be less costly, which will go far to pay the expense of the drying plant. Perhaps a return may even be made to types of stove that were only abandoned because they did not raise the blast to a sufficient temperature.

As to reducing the furnace height, its consequences, though less important, would be appreciable, and at all events the old

furnaces of moderate height now working would be in a better position to compete with the modern giants.

Thus it will be seen that drying the blast may be attended with important consequences and may reopen many questions regarded as finally settled connected with the construction and management of blast furnaces. The author's proposition to make systematic observations on a large number of furnaces working under the most various conditions as regards the influence of the hygrometric degree in the blast would permit of turning Mr. Gayley's invention to the greatest possible account. In a short time the amount of advantage that may be derived from drying the blast, as regards coke saving, increased output and regularity of working, would be definitely determined, while accurate information would be afforded as to the type of furnace which in each special case is best suited for turning these advantages to the greatest possible account.

Utilization of Blast-Furnace Gas

VICTOR DEFAYS

When it was found possible to utilize blast-furnace gas for economically producing motive power, metallurgists regarded this innovation as the dawn of a profound transformation. The first trials seemed to show that the problem was solved almost as soon as stated, and small scale experiments led to applications on a large scale. Difficulties encountered in freeing the gas from fine dust brought a slight check, but soon inventors found means of effectually eliminating dust from the gas, which then became suitable for directly affording motive power.

In achieving this success, however, which greatly improved the value of the gas as regards its utilization in engines, the thermic qualities of the gas as a heating agent were also increased so that the hot-air stoves and boilers fired with furnace gas attained a far higher thermic efficiency than before. This increased value of the gas for heating is due to two circumstances: (1) Elimination of the greater portion of the sublimate which adheres to the surfaces of the stoves and boilers, hindering the transmission of heat by low conducting power. (2) The presence of a quantity, always considerable, of water vapor in the gas, which diminishes its heating power to a large extent.

Too Much Emphasis on Gas for Motors

Now that ironmasters possess a gas very much improved in all respects, especially when freed of its humidity, there is reason to ask whether the utilization of this gas, or at any rate some of it, for firing metallurgical furnaces may not in many cases be more economical than its exclusive employment for generating motive power. The author considers himself warranted in replying affirmatively, although he does not pretend to solve the problem which presents itself under many different aspects according to the circumstances of each case. And the following are his arguments in favor of this view:

1. Purification of the gas need not be carried to such an extent for heating as for motive power.

2. There is a better coefficient of utilization in the former than in the latter case, because in most iron and steel works the demand upon motive power is variable, while there are times when this demand greatly exceeds the mean; for instance, when several large motors have to start simultaneously. The utilization coefficient of gas for motive power in iron and steel works may be put, according to circumstances, at from 40 to 70 per cent, if the blast furnaces themselves, with their blowing engines and other accessories, be left out of the question. But the question is very different with the firing of furnaces which nearly all work continuously. Open-hearth furnaces, for instance, consume day and night a constant quantity of gas, so that the utilization coefficient easily reaches 80 or 90 per cent.

3. As regards the solid fuel burned, nearly all works comprising blast furnaces, steel works and rolling mills must consume, in addition to the furnace gas, a certain amount of coal, either for the production of motive power or for firing the furnaces. Blast-furnace gas for raising steam replaces coal of inferior quality, but when it is used for firing furnaces it replaces gas coal of higher intrinsic value, the gain in favor of the latter utilization being put by the author at 12½ per cent.

Cost of Gas and Steam Power Plants

As regards first cost, it may be considered that the power plant, whether gas or steam, costs about the same, all things considered; but the balance is in favor of utilizing blast-furnace

gas for firing the furnaces, combined with the production of motive power by steam, if it be taken into consideration that the plant for purifying the gas will cost less, and that, except a few simple gas producers in reserve, it will be unnecessary to erect these producers for the open-hearth reheaters and other furnaces.

To sum up: In many cases there will be appreciable advantage in using the waste gases for firing furnaces instead of producing motive power in engines, as is now the general tendency. The slighter purifying of the gas, the better utilization coefficient, the saving in the price of coal used to supplement the gas, and, lastly, the lower first cost, are all in favor of this view. It may also be advanced that steam engines at an electric generating station are more supple and trustworthy, with lower cost for up-keep, as compared with gas engines.

Producer Gas and Furnace Gas

Another paper enters into a comparison of producer gas and blast-furnace gas for firing metallurgical furnaces, and considers that if it be borne in mind that the quantity of carbonic oxide is greater in the latter than in the former gas, and that the former contains a great deal of hydrogen, the calorific value of which at high temperatures is *nil*, or nearly so, and that there is about the same quantity of nitrogen in both, they may be regarded as practically equivalent for firing metallurgical furnaces. This will not hold good for gas engines, because, as their temperature is far lower, hydrogen is a good fuel in their case. It must be added in favor of blast-furnace gas that it may be so far freed from water vapor as to become even dryer than producer gas. In any case, if blast-furnace gas be slightly inferior to producer gas for firing furnaces, the slight difference may be very easily made good by the use of intensive burners, in which a thin, flat jet of gas is enveloped by two similar jets of air, and by a slight enrichment of the gas, which can be effected very cheaply and simply.

As regards the point that has been raised of the radiation of blast-furnace gas, the objection is unfounded that " furnaces heat chiefly by reverberation, which requires a flame of great radiation and consequently illumination, as is not the case with blast-furnace gas, which contains scarcely any other fuel than

carbonic oxide, giving a non-illuminating flame." Carbonic oxide has great radiation, because Helmholtz has shown that the non-illuminating flame of carbonic oxide has a radiating power superior to that of pure lighting gas as burned for illumination.

The author concludes that at works where the blast furnaces are near steel works and rolling mills with gas furnaces it will be more economical to use the blast-furnace gas for firing these latter and to raise steam for the motive power.

Gas or Electric Motor for Roll Driving

CARL ILGNER

The author classes roll trains in three categories, according to the manner in which the power for driving them is utilized: (1) Reversing mills; (2) trains always running in the same direction, but at a speed varying from time to time in the ratio of 3 to 2, while the slowest speed corresponds with the greatest absorption of power; (3) those in which both power and speed are constant. For the first of these classes the gas engine is inapplicable, notwithstanding the attempts made at various works to introduce a reversible coupling between the fly wheel and the roll train.

Electric Drives Successful

Electric driving affords excellent means, not only for easily and certainly regulating the speed, but also for transforming the variable power required by the roll train into one that is almost uniform, in which case there is no doubt of the success of electric driving. Several electric roll trains are under construction, and the preliminary trials hold out the hope of thorough success. If a three-high roll train, the speed of which varies periodically, be coupled with a gas engine, the latter will furnish the greatest amount of power when the speed is lowest. But the products rolled at this slight speed only constitute a third of the whole output, while the remaining two thirds will be rolled at the maximum speed of the gas engine, the efficiency of which will be very slight. It follows that the gas engine will give out a considerable portion of its power while consuming too much gas per horse-power hour. By employing electricity

as an intermediary, the variations of speed are transferred to it so that variation of the load on the motor is diminished. The consequence is that, notwithstanding loss in the electric transmission, and without regard to variation in the speed, gas engines that are no more powerful than those for driving the roll train directly may be erected at the generating station. It is perfectly evident that reversing mills and cogging trains absorb a widely varying amount of power. Electric driving and centralizing the generation of energy present excellent means for regulating motive power, on the one hand by increasing the rotary masses in motion, to which are added those of the fly wheels at the generating station, and on the other by distributing the shocks and the irregularities over the whole generating station. It is evident that the power thus required by the cogging rolls from the gas engines at the central station will be less than that which the rolls would absorb if each were driven directly by its own gas motor.

Possibilities of Centralizing Power

As regards the third class — roll trains of constant speed, which are generally used for plates and small bars — variations of load are not considerable, and in their case electric driving does not afford any great advantage. If, however, it be required to drive roll trains of all three classes, there is no doubt that centralization of the power is preferable to the use of a gas engine for each separate roll train. And to the advantages already claimed for the electric driving of roll trains in classes 1 and 2 must be added those resulting from centralization of the power. The total power absorbed by all the roll trains at a given moment is undoubtedly far less than the sum of the maximum power required by each train.

Another advantage is that the motor of the generating station can receive all the care it requires, because one can be kept in reserve. If the gas engine be coupled directly with the roll train the stoppages required for overhauling will not be compatible with proper working of the train. The electromotor stands overloading better than does the gas engine, while more easily and at less expense it can be replaced by another of greater power. The provision of a reserve for meeting hitches at the blast furnaces or coke ovens is easier at a central station

than for each motor. In the latter case all that can be done is to lay down gas producers more difficult to manage, owing to intermittent working. At the central station, on the contrary, a steam turbine with a bank of gas-fired boilers constitutes a trustworthy reserve.

In short, a whole series of weighty considerations count in favor of centralization. If it be considered that at the central station much less power plant will need to be laid down, while larger motors may be employed, and, if again, the connections of each train and the long gas pipes be considered, the conclusion is warranted that the first cost will not be an obstacle to adopting the principle of central electric stations. The difficulties encountered in the progressive transformation of works must not be disregarded, but it appears undeniable that centralizing the motive power of rolling mills, with electric driving and the use of blast-furnace or coke-oven gas, gives promise of great economy as compared with present practice.

IRON RESOURCES OF THE WORLD *

By R. ANSPACH

PROF. A. E. TÖRNEBOHM, president of the "Sveriges Geologiska Undersökning," has made an exhaustive report to the Swedish parliament, from which is taken the information embodied in this paper.

In inquiring into the extent of the world's iron resources, we must remember that, in the very nature of such an investigation, it cannot be solved with any great degree of accuracy, not even when only one country is considered, and still less for a whole continent or the entire globe. For, on the one hand, the location of ore deposits is known with tolerable accuracy only in more or less civilized regions; while, on the other hand, it is in many cases unknown how rich the various deposits may be at greater depths. In addition to this, there is much uncertainty as to what character of ore may properly be taken into account in estimating ore supplies. For, besides the unquestionably good ores, there are large quantities which are of less value, either

* Translated from the "Zeitschrift für angewandte Chemie," "Engineering and Mining Journal," October 7, 1905.

owing to their composition or to their low iron content, or from both causes. But there is a continual endeavor to find the means for exploiting these ores of lower value, and the marvellous development of the iron industry within the last twenty or thirty years has been largely the consequence of progress made in this direction.

To quote only a few familiar instances, the reader will recall how the Thomas method for working up phosphorus-bearing ores called to life the Norbotten fields, and the still far more extensive industry based on the minette (oölite) ores of Lorraine; he will further remember how the success recently achieved in the magnetic concentration of ores has laid the foundation of a gigantic undertaking for exploiting the low-grade, but otherwise highly important, Dunderland ores in Norway. All these ores were, before these improvements, regarded as almost unworkable; and so the question naturally arises whether other ores, which at the present day are considered practically worthless on other grounds, may not perhaps some day acquire importance through further technical progress. Regarding ores belonging to this last class, data of any value are so meager, so far as foreign deposits are concerned, that it will be necessary to leave them out of account altogether in these considerations.

On the Swedish iron ore fields Professor Törnebohm has collected the following material, for which absolute accuracy cannot be claimed, as was pointed out above, and which is based in part on rough estimates.

Norbotten. — According to the latest investigations the ore supply in this district may be estimated as follows:

Kirunavara: Ore above the level of Luossa jarvis	265,000,000	tons
Ore beneath the same, down to a depth of 300 meters	510,000,000	,,
Luossavara.....	18,000,000	,,
Total.....	793,000,000	,,

The ore is exceedingly rich; it contains 65 to 70 per cent iron throughout, and the phosphorus runs high — 1 to 2 per cent as a rule. Most of the ore (80 per cent) is exported to Germany. In England there has as yet been little demand for the ore, as only a few iron works have taken up the basic method (Thomas method), by which it has become possible to produce good iron from phosphorus-bearing ores. But, according to recent in-

formation, this method is finding more and more application in England also.

Gellivare. — The ore supply in Gellivare, abovethe railway line, is estimated at 53,800,000 tons and down to a level 100 meters below this line at 49,700,000 tons; altogether, therefore, at 103,500,000 tons. But as ore is undoubtedly still found at greater depths than that indicated (at any rate, in the more important mines), we may, without danger of overestimate, add a quantity of at least one half of that lying within 100 meters beneath the level of the railway line — that is to say, in round numbers, 25,000,000 tons; so that the total ore supply in Gellivare may be estimated at 128,500,000 tons. The iron content of the ore is 55 to 65 per cent; the phosphorus varies widely, but is considerable throughout.

The most important of the remaining Norbotten iron fields are: Ekströmsberg, Mertainen, Svapavara, Tuolluvara and Leväniemi. The quantity of ore in Ekströmsberg is estimated at about 100,000,000 tons; that in Mertainen and Laukujärvi at about 5,000,000 tons. The percentage of iron in these two fields is 55 to 65; the phosphorus is rather high in Ekströmsberg, low in Mertainen. There are no estimates available of the other three fields, but they can be roughly gauged according to the known area of the ore deposits. This area is:

Svapavara,	50,000 square meters	12.355 acres
Tuolluvara,	10,000 ,, ...	2.471 ,,
Levaniemi,	40,000 ,, ...	9.884 ,,
Total	100,000 ,, ...	24.710 ,,

Supposing these fields to be worked to a depth of 200 meters, and reckoning 3.5 tons of ore to the cubic meter, gives 70,000,000 tons as the total quantity of ore. The percentage of iron in this field is 60 to 70; the phosphorus is comparatively low in Tuolluvara, while in the other districts it varies a great deal, though it is high throughout. The stock of ore in the chief iron fields of Norbotten, is, therefore:

Kiruna — Luossavara.....	793,000,000 tons
Gellivare.....	128,500,000 ,,
Ekströmsberg.....	100,000,000 ,,
Mertainen Laukujarvi	5,000,000 ,,
Other mines.....	70,000,000 ,,
Total.....	1,096,500,000 ,,

Central Sweden.— The ore supply of Grangesberg, down to 300 meters below the surface, is estimated at 60,000,000 tons. The ore supply in the numerous other iron mines of central Sweden can, at the present time, be estimated only roughly, according to the area of the fields. This may be taken to be about 200,000 square meters (49.42 acres). As the more important mines are already much attacked, we may assume that they cannot on an average be worked further down than for another 100 meters. Assuming that each cubic meter yields 2.25 tons of ore, the total quantity of ore would be 45,000,000 tons. On this basis the total ore supply for central Sweden is, therefore, 105,000,000 tons, and for the whole realm, in round numbers, 1,200,000,000 tons.

Two important ore deposits — Routivare in Norbotten and Taberg in Smaland — have not been taken into account above, as their ore is highly titaniferous, and, therefore, does not reach the market. For Routivare the area of deposit is given as 300,000 square meters (74.13 acres). This, however, rather represents collection of nodules of ore than a continuous deposit, and it is, therefore, uncertain whether the depth corresponds at all to the area of the district. It is at present impossible to estimate the quantity of ore.

Taberg has an area of about 260,000 square meters (64.25 acres). The ore body is more collected here and probably has a considerable depth, but the iron content is low (in the richest parts 30 to 40 per cent); this, together with the high percentage of titanium (5 to 6 per cent), has hitherto prevented the exploitation of the ore.

Foreign Iron Deposits. Norway. — In recent years several important deposits of iron ore have been discovered in the northern part of Norway. The most important are the Dunderland, the Naeverhaugen and the Sydvaranger districts. So far as the area of the deposits is concerned, these much surpass the Norbotten fields, but the ores are, on the whole, poor (30 to 40 per cent). Large installations for exploiting the Dunderland ores are in the course of erection. The ores that can be reached by surface working alone are estimated at 80,000,000 tons. It is proposed to concentrate magnetically to 62 to 64 per cent, to briquette the ore and to export annually to England 750,000 tons, there being a good demand for it there, owing to its low phosphorus content. In Naeverhaugen and Sydvaranger no

estimates of any account have, as yet, been made of the ore deposits. Statements regarding the quantity of ore differ a good deal; the iron content varies between 30 and 58 per cent, but is said to be 38 per cent on an average.

Outside of Scandinavia the countries which at present chiefly produce iron ore in quantities affecting the world's market are England, Lorraine, Spain, southern Russia and North America.

England. — The older English iron fields are now mostly exhausted, and therefore abandoned. Most of the fields at present under operation have been opened up within the last ten years, as the Cleveland, West Cumberland, Lincolnshire, Northampton, Derbyshire, Notts, Leicester and Oxfordshire fields. The most important of these are the Cleveland fields, in which, however, the iron runs low (about 30 per cent), and moreover appears to be going down still further. In the year 1850, when the Cleveland field was first opened, the ore supply was estimated at from 4,000,000,000 to 5,000,000,000 tons. Since then about 250,000,000 tons of the best ore have been extracted, and what still remains of such ore will be exhausted in about twenty years' time. The ore that will then be left is, in general, of such poor quality that, with the present machinery and methods, it would not be considered worth mining. The condition in the other English iron ore districts is much the same as in the Cleveland fields. The iron ore production of Great Britain is decreasing. It reached its maximum in 1882, with 18,000,000 tons; it is now about 12,500,000 tons, of which Cleveland contributes 40.2 per cent; Lincolnshire and Northamptonshire, 26.7 per cent; Cumberland, 11.7 per cent; Scotland, 6.2 per cent; and Staffordshire, 6.1 per cent. The annual consumption of ore in England is, at the present time, 20,000,000 tons. The deficit (some 6,500,000 tons) is covered by importation, chiefly of Spanish ore.

Lorraine and Luxemburg. — The minette (oölite) ores which occur here are of the greatest importance. They contain 35 to 40 per cent iron and 0.7 to 0.8 per cent phosphorus. The ore supply is thus estimated:

German Lorraine	1,835,000,000	tons
French Lorraine	1,300,000,000	,,
Luxemburg	300,000,000	,,
Total	3,435,000,000	,,

The minette ores at present furnish 80 per cent of the total production of Germany, and 66 per cent of that of France.

Spain. — The principal iron district of Spain is the Bilbao field, on the north coast. The iron content of the ore there runs from 50 to 55 per cent; the phosphorus is insignificant. The original stock, once so extensive, is now greatly broken into, and the production is decreasing. In the year 1899 it amounted to 6,5000,000 tons; in 1902 to 4,700,000 tons. This supply will presumably be exhausted in ten or twenty years. The ore is exported chiefly to England, which, of late years, has received about 3,000,000 tons annually. In several places new fields have recently been discovered in Spain, and mining has been begun on some of these, as for instance in Castile; in Asturia (where are several deposits with an aggregate stock estimated at about 200,000,000 tons); in Sevilla Granda canal, 20,000,000 to 30,000,000 tons; in Paderoso, 10,000,000 tons; in Tornol, 50,000,000 tons; in Huelva (Cala), 18,000,000 tons; also several deposits near the Mediterranean Sea, making a total stock of between 50,000,000 and 60,000,000 tons.

Southern Russia. — There are here several important iron fields, the two most important being Krivoi-Rog and Kertsch. In the former the iron content is 50 to 65 per cent, the phosphorus as a rule less than 0.1 per cent. According to the most recent statements, the stock of ore there is taken as 87,000,000 tons (older calculations gave much lower figures), which should be exhausted in some thirty years' time. The production amounted to about 2,500,000 tons in 1903, of which the greater part was exported. The percentage of iron in the ore of the Kertsch peninsula is 30 to 40, higher only in exceptional cases; the phosphorus runs from 1 to 2 per cent. The stock is figured at 846,000,000 tons, of which, however, only perhaps 13,000,000 tons have an iron content of 37 per cent or more.

North America. — The principal iron district in North America lies south and west of Lake Superior, in the United States. On the Canadian side of the lake there are also a few iron fields, but these are of comparatively small importance. There are other iron fields in Alabama, Virginia and Tennessee. The total production of iron ore in the United States in 1902 was 36,000,000 tons, of which the Lake Superior field contributed 28,000,000, Alabama, 3,500,000, and Virginia and Tennessee,

1,800,000 tons. The Lake Superior ores are in part rich, with 55 to 60 per cent iron and 0.04 per cent phosphorus. The stock of such ores has been quoted at 1,000,000,000 tons, but this, according to more recent estimates, is too high. It is believed that this supply will be exhausted before the middle of the present century.

Until the year 1900 these mines produced exclusively ore with a minimum of 60 per cent of iron. Since then the practice of mixing the rich ore with poorer material has become more and more widely established, so that the ore now produced does not contain more than 52 to 54 per cent of iron. The oldest of the Lake Superior fields was opened in 1854, the youngest (the Mesabi) in 1892. The latter is now the most productive (13,000,000 tons in 1903). Until 1903, inclusive, 253,000,000 tons had been mined. The ores must be shipped to the blast furnaces over very long distances (1,000 to 2,000 kilometers = 620 to 1,240 miles), mostly, however, by water. The ores in Alabama contain 45 to 48 per cent iron, with a rather high percentage of phosphorus. There are coal measures near by. The known range may be estimated at a low figure to hold from 50,000,000 to 60,000,000 tons, but probably the deposits extend considerably beyond the field hitherto examined.

In addition to the ore deposits considered above, there are still a large number of others, on which little or no mining has hitherto been done. As the foremost among these should be mentioned the iron ore range in the province of Shansi in northern China. In this district coal measures extend over at least 35,000 kilometers, with which iron ores are associated over a large part of the region. For 2,500 years past the main portion of China's iron consumption has been supplied from these ores, but nevertheless the stock is only slightly attacked, and a very extensive supply is still left over.

New ore fields have also been discovered in Ireland (county of Antrim, calculated quantity of ore, 6,000,000 tons; iron content, 30 to 50 per cent), in the Cyclades, Algiers, the Soudan, Cameroon, India, Tongking, Cuba, Peru, Mexico, New Mexico, Utah, Oklahoma, Canada, New Caledonia, Western Australia, etc. Regarding these deposits, however, no reliable information is at present forthcoming.

The following table, showing the yield in 1901 of the iron ore

districts of different countries, gives an idea of their relative importance for the world's production:

	Tons
United States	29,730,000
Germany (including Luxemburg)	16,840,000
England	12,470,000
Spain	8,030,000
Russia	5,900,000
France	4,870,000
Sweden	2,840,000
Austria	1,920,000
Hungary	1,660,000
Newfoundland	750,000
Greece	530,000
Algiers	520,000
Belgium	260,000
Italy (Elba)	240,000
Bosnia	130,000
Other countries	620,000
Total	87,500,000

The probable development of the iron ore situation in the future can be summed up in the following paragraphs:

1. It can be foreseen with certainty that the iron ore fields of North America, Germany and England will be exhausted within one or two centuries from now; those bearing comparatively rich ore much earlier, even.

2. A decline, or the entire dying out, of the iron industry in consequence would take place only in England, as in that country the coal will be used up about the same time. (It has been calculated that the coal fields in Durham and Northumberland will run out in about 100 years, the other English coal fields in from 250 to 300 years.)

3. In Germany and North America the deficit in the home production of iron ore will be covered by importation, in accordance with the well-known rule that the ores travel to the coal fields, and not *vice versa.*

4. Apart from the countries in which industries are flourishing at the present time, only northern China has the requisite conditions for the development of an extensive iron industry, as only there are coal and iron found associated together. Should it, however, at some future time become possible, through technical advances, to recover iron from the ore with consumption

of little or no coal, a revolution in the state of affairs would take place, the consequences of which can hardly be appreciated now.

5. The iron production in the coming century will in the main depend: (*a*) On ores occurring in countries opened up to industry at the present day, but having hitherto received no attention, either on account of their low grade, or owing to their being otherwise unsuitable; (*b*) on the development of new mining districts in lands as yet little touched by geological exploration.

6. The location of the future centers of iron production will be determined by the position of the coal fields, and by the conditions of transport. These two factors, together with the metallurgical progress in dressing the ores, will decide the course of the iron production in the future. The supply of ores to cover the world's iron consumption will presumably never be exhausted.

SHALL WE SUBSTITUTE IRON FOR STEEL?*

AS many of our readers will recall, we published two years ago articles from a large number of different contributors describing experience with iron and steel pipe and with other articles made of iron and steel, which showed apparently that steel corrodes much more rapidly than iron. We present in this issue considerable additional data from a discussion at the Washington meeting of the American Institute of Mining Engineers (the report of which has just become available for publication). This discussion confirms the opinions previously expressed and goes still further in showing the rapid rate of corrosion of much of the steel made at the present day.

The Department of Agriculture at Washington is proceeding with an investigation as the result of complaints by farmers throughout the west, who declare that their wire fences, which were formerly good for thirty years of life, now begin to fail by the end of three years. Steel wire nails, steel plates, coated with tin and used for roofing, steel boiler tubes and steel structural material are among the other products concerning which complaint is heard because of the rapid rate of corrosion.

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*"Engineering News," September 28, 1905.

It is to be noted also that the importance of corrosion and the limitation which it sets to the life of a structure are just beginning to be fully appreciated by engineers, and in a lesser degree by those who employ engineers. Forty years ago it used to be considered that a wooden bridge was a temporary structure and an iron or steel bridge a permanent one. But there are wooden highway bridges still standing and in good condition in this country which were old structures when steel highway bridges first became common, and which have witnessed already the final end of many of these same steel bridges. Of course the great cause — and the one usually assigned — for the replacement of an iron or steel bridge is that the traffic has outgrown its capacity; but it is also true in most cases that corrosion has greatly reduced the original strength. Who can doubt that the engineers who built the iron structures that were erected forty years ago, or at least those who paid for them, would be disappointed to-day to realize how poorly their work on the whole had withstood the ravages of time and how nearly it had reached the limit of its life.

We at the present day have the advantage of experience which they lacked. We can estimate closely — or ought to be able to — a rate of annual depreciation, where they could only guess, and it is an important question whether even more attention ought not to be given to the matter of durability and resistance to corrosion in the design of all sorts of engineering work.

Unquestionably this is already being done to a large extent. The enormous use of concrete, and of reinforced concrete, and the renaissance of the masonry arch, are evidence that durability counts for more than cheapness of first cost with many users and their engineering advisers; but unless all our information is at fault we ought to go farther and return to the use of iron for many purposes for which steel has become the customary material, or else find some method of making steel reasonably resistant to corrosive influences.

There are two things which greatly hamper the engineer who wishes to employ iron instead of steel because of its greater durability. He may write a specification calling for iron pipe or nails or plate or sheets or wire, but how can he tell whether the material he receives is iron or steel without resorting to some difficult and expensive chemical tests? And the retail

dealer is no better off than the engineer, or as well off, perhaps. In the second place, suppose the engineer does specify iron, can he be sure that the iron he receives will be a satisfactory material? Iron fresh from the puddling furnace is used for selected brands of boiler flues, stay-bolts, etc., but more or less of the wrought iron of the present-day market is made from scrap. The constitutents of the scrap pile from which that iron was created are so varied and there is such large chance of steel forming part of it and introducing the probability of non-homogeneity and flaws that the engineer may be excused for hesitating before he demands iron instead of steel.

Clearly, then, the increasing use of wrought iron is closely dependent on a reliable supply of wrought iron produced from the ore, but the difficulties in the way of re-establishing the old hand puddling system are many. A mere comparison of the interior of an old-time puddling mill and a modern open-hearth steel furnace plant will show that the one represents a maximum of hand labor, while in the other machinery, intelligently controlled, has largely replaced human muscle. In order that wrought iron may come into much more extensive use, some process is needed by which wrought iron can be produced on a large scale, with the minimum of hand labor, and with a product equally reliable to that produced by the old method. A process which appears to fulfill these conditions is that invented by Mr. Jas. P. Roe, of Pottstown, Pa., and described in a paper published in our issue of May 7, 1903. The expert comments on Mr. Roe's process made at the Washington meeting of the Mining Engineers were highly favorable and certainly indicate that a way has been found whereby wrought iron can be produced at as low a cost as good steel.

Of course steel may be expected to hold its present place in many fields and probably in most. Wherever hardness and resistance to abrasion are important qualities, as in railway rails, it is, of course, infinitely superior to wrought iron. Wherever facility of welding or resistance to corrosion is an important factor, the superiority of wrought iron must be admitted.

A question of much interest in this connection and one which is still unsolved, relates to the cause of corrosion in steel. Cast iron is known to be more resistant to corrosion than either wrought iron or steel. In the early days of the Bessemer and

open-hearth process it was naturally supposed that its product, being intermediate in its carbon content between cast and wrought iron, would be also intermediate as respects susceptibility to corrosion. It was not until years of experience with very soft steel had been obtained that the greater liability of steel to corrosion was definitely determined. Even now it is possible to find engineers who maintain that steel resists corrosion as well as wrought iron. It is not long ago that there came to our notice in the advertising literature of a wire manufacturer the claim that the fence wire now made was as good as that ever produced and that the reason the wire corroded so much more rapidly than formerly was the greater amount of gas in the air due to the increased consumption of coal in locomotive and other boilers!

As to the real reason why soft steel corrodes so rapidly engineers and chemists are, so far as we are aware, almost wholly in the dark. It is, of course, quite within the possibilities that the cause may yet be discovered and that it may then prove feasible to so alter the chemical constitution as to make the steel longer lived. Certain alloys — nickel — for example, are known to greatly increase the resistance of steel to corrosion; but their cost makes their extended use quite out of the question. Phosphorus is also believed to increase resistance to corrosion, but its favorable influence in this direction is far more than counterbalanced by its injury to the physical qualities.

These problems, however, must be left to the chemists. Until they are solved the engineer who considers the durability of a structure exposed to corrosive influence will prefer wrought iron to steel.

GREAT BRITAIN'S IRON INDUSTRY *

By T. GOOD

THE future development of the British iron trades, upon which the commercial prosperity of the country so largely depends, is a subject not only of great interest, but of some anxiety. New circumstances, new conditions of foreign competition, have arisen; where once there were customers there are now rivals. Great Britain must recognize that it has no longer an absolute monopoly in any branch of industry; that in some directions it has already lost the leading position; that in others it is being more or less rapidly overtaken; and it is a question whether the British are not laboring under some unfair conditions of fettered enterprise and restricted effort against which they cannot reasonably hope to struggle successfully in the future as competition becomes keener.

It is not the object of the writer to take any part in the fiscal controversy, nor to sound any note of pessimism; he holds that there is nothing in this growing competition to be afraid of, nothing to frighten either capital or labor, and that there is no need to adopt any ill-conceived measures or doubtful experiments in the interests, or alleged interests, of British industry, but he begs to urge the imperative need of cultivating a more ready adaptability to new ideas, new times and new circumstances.

Great Britain's proud position in the world of trade and commerce was not attained without effort, nor will it be retained without exertion. The time is here when it cannot well afford to ignore a single commercial obstacle or industrial blight which it is possible to remove. Wherever there is room for improvement in method or policy, that improvement has got to be made without undue delay, or prosperity has got to suffer. And, with the possible exception of agriculture, in no direction is there greater need for improvement than in the foundations of the British iron industry.

Before offering any criticism of present methods, or making any effort to forecast the future, let us take a glance backward. Half a century ago Great Britain produced as much pig iron

* "Cassier's Magazine."

as the rest of the world combined. In 1855 the output was 3,200,000 tons. From that time the actual, but not relative, output steadily increased until 1872, when it produced 6,741,929 tons, valued at over £18,500,000. Then the output declined steadily until the production for 1879 fell to 5,995,337 tons, valued at less than £15,000,000. Each of the next three years showed a slight increase, — the production of pig iron in 1882 being 8,586,680 tons, of a net value of £24,042,704. During the years 1883, 1884, 1885 and 1886 production and price fell, until the year 1886 showed but 7,009,754 tons, worth £15,888,775.

By 1889 it had improved up to an output of 8,322,824 tons and a value of £20,390,918, while the following year, for a smaller quantity, producers received over £24,000,000. Then both quantity and value fell to 6,709,255 tons and £17,276,332 in 1892, and to £15,898,445 for an output of 6,976,990 tons in 1893, which was the year of the coal strike in the Midlands, — the strike having commenced on July 28 of that year. During 1894, 1895, 1896, 1897 and 1898 there was a steady improvement. In 1899 a record in quantity was established, and in 1900 a record in price, the figures being: 1899, £32,661,373 for 9,421,435 tons; 1900, £37,622,549 for 8,959,621 tons. Since then the output has slightly decreased and the value has considerably declined. In 1903 about 8,800,000 tons of approximately £22,000,000 value were produced, and in 1904 about 8,500,000 tons of about £21,000,000 value. Table I gives the British output of pig iron in the five-year periods from 1854 to 1900, and separately for the last six years.

Years	Quantities in Millions of Tons	Years	Quantities in Millions of Tons
1855–9	3.5	1895–9	8.7
1860–4	4.2	1899	9.4
1865–9	5.0	1900	8.9
1870–4	6.3	1901	7.9
1875–9	6.4	1902	8.6
1880–4	8.1	1903	8.8
1885–9	7.5	1904	8.5
1890–4	7.3		

As recently as 1874 Great Britain produced 47 per cent of the world's iron; in 1890 it produced but 27 per cent, and last year not more than 17 per cent. As iron producers, the British

held first place until 1895, when the United States got ahead of them; in 1903 they failed to retain even second position, — being beaten by Germany. While the world's demand for iron and iron goods has increased enormously, British production has remained practically stationary. Whether we go back ten years, or twenty years, or thirty years, we find that Great Britain's actual output of iron has not materially increased, while relatively to the world's demand for, and comparatively to its rivals' production of, iron it has lost ground to a very considerable extent.

While in iron production the British have been standing still, and, per head of population, losing some ground, other nations have been going ahead by leaps and bounds. During the last twenty years the French have increased their output by about 30 per cent; the Belgians by 50 per cent; the Germans by 300 per cent, and the Americans (United States) by about 400 per cent. Twenty-four years ago Great Britain produced $4\frac{1}{2}$ cwts. of iron per head of population annually; to-day, when the world is using double, if not treble, the quantity of iron it did then, the British are only producing 4 cwt. per head. During this decline from $4\frac{1}{2}$ to 4 cwt. on per capitum basis, Germany has increased from 1 to $3\frac{1}{3}$, and the United States from $1\frac{1}{4}$ to $5\frac{1}{4}$. This proves that the British are losing their grip on the world's iron market. This would not matter so much from a national standpoint but for the fact that in another great branch of manufacturing industry, viz., textiles, no progress relative to increase of population has been made in Great Britain during the last quarter of a century so far as the supplying of other markets is concerned, while in agriculture there is shocking and shameful lack of enterprise and progress.

And not only are the British being elbowed out of markets abroad in which there is an ever-growing demand for iron and iron goods, but they are being undersold in the home markets. During twenty-five years, while British exports of iron and steel and manufactures thereof have increased by but a fraction per head of population, their imports of these things have increased by 300 per cent. Excluding iron ore and scrap (raw material), the United Kingdom is now spending a round twenty million pounds sterling per annum in foreign iron and iron goods, and this while one third of their blast furnaces stand idle.

TABLE II. IMPORTS OF IRON AND STEEL AND MANUFACTURES THEREOF INTO THE UNITED KINGDOM

VALUES IN MILLIONS OF POUNDS DURING DIFFERENT YEARS

Description	1880	1885	1890	1895	1900	1901	1902	1903	1904
Iron and steel of all kinds, except machinery and ships	2.2	3.7	3.4	4.4	7.7	7.5	7.9	8.6	8.2
Iron ore and scrap	2.7	1.9	3.5	2.9	5.6	5.6	5.0	4.8	4.5
Engines and machinery	...	...	...	...	3.6	3.9	4.7	4.4	4.3
Cutlery, hardware, implements, instruments, tools, etc., except musical instruments	...	...	...	...	2.0	4.3	4.4	4.2	3.7
Ships (new)	...	...	...	...	...	...	...	0.06	0.02
Motor cars and cycles	...	...	...	...	...	...	1.1	1.9	2.4
Cycles (not motors)	...	...	...	...	...	...	0.14	0.9	0.8
Telegraph cables, etc.	...	...	...	...	...	...	...	0.05	0.05
* Totals (except iron ore)	3.0	4.1	4.7	4.6	14.2	22.5	23.4	24.4	23.5

TABLE III. EXPORTS OF IRON AND STEEL AND MANUFACTURES THEREOF FROM THE UNITED KINGDOM

VALUES IN MILLIONS OF POUNDS DURING DIFFERENT YEARS

Description	1880	1885	1890	1895	1900	1901	1902	1903	1904
Iron and steel of all kinds, except ships and machinery	28.4	21.7	13.5	19.6	32.0	25.0	28.8	30.4	28.0
Iron ore and scrap	....	....	....	....	....	....	0.3	0.4	0.5
Engines and machinery	9.2	10.6	15.7	14.2	18.1	17.8	18.7	20.0	21.0
Ships (new)	....	....	....	....	8.5	9.1	5.8	4.2	4.4
Cutlery, hardware, implements, instruments, tools, etc.	4.5	4.0	4.4	3.3	4.0	4.1	4.3	4.6	4.8
Motor cars and cycles	....	....	....	....	....	....	0.17	0.34	0.67
Cycles (not motors)	....	....	....	....	....	....	0.7	0.8	0.7
Telegraph cables, etc.	....	....	....	....	....	....	2.8	1.8	0.8
* Totals	42.1	38.30	47.5	50.0	64.0	59.0	63.7	64.3	62.8

Ships not included until 1900.

* Including articles not enumerated here.

That America has some natural resources superior to Great Britain will be readily admitted, although these are considerably exaggerated from time to time. But the disadvantages under which the British labor as compared with their American rivals are much more artificial than natural, while in contrast to Germany's progress, natural advantages cannot be urged in explanation. The indisputable fact is that the great progress in the production and manufacture of iron is primarily due, alike in Europe and America, to low mining royalties, low transit rates, and a ready adaptability to new inventions and ideas compared with the conditions prevailing in Great Britain.

The problem of trade is the problem of cheap and rapid production and transit, and whatever position Great Britain has attained in the past when, in an industrial sense, other nations were slumbering, it cannot reasonably expect to retain its supremacy in the face of keen competition if it continues to tolerate the present excessive rents, royalties and transport charges, and to pursue generally a too conservative policy in industrial and commercial affairs.

The British stick too tenaciously to antiquated appliances and ancient ideas. Take, for instance, blast-furnace practice. The output per furnace in Germany is fully one third more, on the average, than in the United Kingdom. With fully 50 more furnaces in blast last year than had Germany, the British production of iron was nearly 2,000,000 tons below that of their rivals, while in America, in 1903, 250 furnaces produced over 18,000,000 tons of pig iron as against 350 in Great Britain giving an output of less than 9,000,000 tons.

The United States, having adjusted their recent financial disturbances, are now producing pig iron at the rate of 22,000,000 tons a year, and there is evidence to support the belief that American exports of iron and iron goods will shortly assume proportions distinctly detrimental to the British. A good number of American furnaces, with their modern equipments, produce from 400 to 500 tons of pig iron daily, and an output of 800 tons per day has been attained by special effort in at least one case. An output of 300 tons per day is quite exceptional in Great Britain.

The high-capacity furnaces of America, with their pig-iron casting machines, whereby the work on the old-fashioned sand-

bed is avoided, to mention but one point, have materially aided the American industry. Then, again, the cost of labor both in the mining and manufacture of minerals is less in America than in Great Britain. Electric coal-cutting machinery, and other mechanical appliances in the mines, at the coke ovens and smelting furnaces, are much more extensively used than in the United Kingdom. The utility of these appliances is at once apparent when we note that against the British output of 275 tons of coal per year per man employed in and about the mines, the output in America is 526 tons. There are over 7,000 coal-cutting machines at work in the United States, and they have reduced cost by from 15 to 30 cents per ton.

However, the British manufacturer has quite a plethora of candid critics continually tendering advice gratis, and advice at so much per column, and while, as a practical man, the writer of this article is well acquainted with the manifold shortcomings of the average British manufacturer and workman, he contends that there is another audience — the landlords — to which the critics of British industrialism should address some of their strongest remonstrances.

A great deal has been heard within recent years of land bills and fair rents courts for Ireland; it is time a move in this direction was made on behalf of the industries of Great Britain. It is an indisputable fact, blink it as we may, that the unfettered and unique land monopoly of the United Kingdom constitutes the heaviest burden now suffered by British industry and is the cardinal point in the problem of foreign competition. Hitherto, the British have prospered in spite of the land laws simply because they had no formidable competitors in manufactures, but now that other nations are developing their mineral resources, manufacturing for themselves and for export, copying the best British methods but discarding the worst ones, assisted by enlightened land laws and transit facilities, the time is at hand when the British must set about in earnest to mitigate the evils of rents, royalties and railway rates excessively burdensome compared with those enjoyed elsewhere.

Cheap transport charges and low rents and royalties have been the primary factors in the rapid industrial development of Germany and America, and the British cannot reasonably hope to hold their own against these rivals unless they very materially

reduce their cost of carriage and their mining royalties. Some ten years ago the Iron Trades Delegation to the Continent, upon their return, gave it as their opinion that if British ironmasters enjoyed the same mining royalties and railway rates as those of their rivals, foreign competition in neutral markets could be defied. And there was, and is, ample evidence to justify such a contention.

From a geographical standpoint the transit facilities of Great Britain should be superior to, and their cost cheaper than, those of their rivals. But as a matter of fact,— thanks to a monopoly that has charged the railways such scandalous prices for land that they are saddled with capital charges twice and thrice as heavy per mile as those of other countries,— the British railway rates are notoriously oppressive compared with those prevailing elsewhere, while the canal system is so antiquated and inefficient as to constitute a positive disgrace to an industrial community.

What has been done in the matter of throwing heavy capital charges upon the railways cannot very well be undone, but by insisting upon having land at reasonable prices for the further extension of railways, by more intelligent coöperation among traders and between traders and railway companies, and by a much-needed development of the waterways, the cost of carriage could be materially reduced and the trade of the country materially increased. As it is, the railway rates for iron goods from works to port, distance for distance, are on the average 115 per cent higher than those of Germany, 120 per cent higher than those of France, and 300 per cent higher than those of Belgium and America, while cases could be quoted where on the railways of America and on the splendid canals of Germany the cost of carriage for iron ore and other minerals is but one sixth of the cost in the United Kingdom.

Another grievance which calls imperatively for redress if Great Britain is to remain a great iron manufacturing nation is in the matter of mining rents and royalties, — another phase of the land monopoly. In the various charges termed fixed rents, dead rents, lease-fees, wayleaves, waterleaves, airleaves and royalty per ton of minerals raised, there is a list of extravagant, exorbitant and extraordinary tariffs levied unjustly upon British industry. These royalties — to group the various

charges under one heading, for they are all royalties upon, and add to the cost of, mining — average not less than one shilling per ton of coal.

This tax upon the production of coal, which is in turn a tax upon the general industry of the country, and especially upon the iron and steel trades in which so many tons of coal are used in the manufacture of a single ton of finished goods, is a much more serious matter than is generally recognized. On the most moderate computation it is possible to make, the average royalty on a ton of British pig iron from iron stone, limestone and coal, is not less than six shillings. And this pig iron with its tax is but raw material for the manufacturers, further quantities of coal having to be used in working it up. These mining royalties are fair examples of how public well-being is sacrificed to private privilege in Great Britain.

In Germany, mining royalties are fixed by the state at 2 per cent on the profits of the undertakings, and no prejudice of the landowner is permitted to prohibit the working of minerals; in Belgium, at $2\frac{1}{2}$ per cent on profits; in France, all coal and ironstone being the property of the state, at 5 per cent on profits, while rents are merely nominal, being about $\frac{1}{2}d.$ per acre, as against British rents of from £2 to £5 per acre on top of the lease-fees which are often excessive and sometimes prohibitive. In Spain, also, mining rights are leased on nominal terms, and in the United States royalties are practically unknown. While in Great Britain mining royalties are a burdensome tax on production, in the case of their Continental rivals they are only a moderate charge on profits, and herein lies a solid grievance.

Now, suppose the British make a profit of two shillings per ton in mining operations, or, what will serve the purpose of illustration better, suppose no profit whatever is made, the royalty charges will in any case reach about one shilling per ton. But if the Germans make two shillings profit, their royalty will be one halfpenny; if they make one shilling profit they will pay but one farthing; while if they make no profit they pay no royalty. But in the former case, whether profits are made or not, whether the British can or cannot hold their own in the matter of price with competitors, the landlords' charges have to be met, or operations must cease.

The whole system of granting mining leases in Great Britain

is fundamentally wrong, and is utterly opposed to industrial welfare. A lease is conceded for a term of years upon conditions mutually agreed to by tenant and owner, but when the lease expires and the tenant company — their plant in full working order and their business established — desire a renewal, it can be obtained only on the landlord's terms, and if trade happens to be good at the time, these terms are liable to be based on "boom" figures. Then, in the course of a few years, if trade slackens and prices fall and the landlord is not of a generous disposition, the inevitable collapse comes, — investors are ruined, workmen are turned adrift and the plant becomes the property of the landlord.

This is no uncommon case. Quite recently the writer saw a mine idle, the machinery in a state of decay and the cottages deserted simply through excessive royalties which could not be paid during a period of temporary depression. And this mine is situated where all the natural conditions are favorable to the industry; but, as often happens, one man is permitted to set the laws of nature and the needs of the community at defiance.

To further illustrate how these mining royalties handicap British industry it may be mentioned that some iron manufacturers pay more in the shape of royalties than in wages, and that the royalty charges on the bunker coal of a steamship amounts to more than the crew's wages. The writer knows of one case — a coal mine in Scotland — where the landlord's toll amounts to 3*s.* 6*d.* per ton of coal raised. He knows of another mine in Yorkshire paying no less than £40,000 a year in royalties on the output of two shafts. He could quote the case of a firm paying over £11,000 a year in royalties, but whose shareholders for nine consecutive years were without a dividend; another firm paying as much as £100,000 a year in royalties but nothing in profits for several years; and yet another — this time a typical, not an exceptional, case at all — paying £80,000 yearly in royalties, whereas a firm on the Continent with a similar output and making a similar profit would not pay so much as £3,000 a year in royalties.

In reference to railway rates and mining royalties taken together, the writer will quote the case of a Yorkshire firm in competition with a Belgian firm for an order from the London County Council for rails. This firm uses Lincolnshire or Northamptonshire ironstone upon which royalties amount to more than

a shilling per ton, but to avoid exaggeration we will put it at one shilling. It takes 4 tons of this ironstone to make one ton of rails. This makes, in ironstone alone, 4 shillings per ton of rails in royalty.

In the manufacture of this ton of rails there are used $3\frac{1}{2}$ tons of coal. Taking the royalty upon coal to be only 6*d.* per ton, to again avoid exaggeration, and reckoning the royalty upon limestone to be only 3*d.*, we have here, on coal, ironstone and limestone, royalties amounting to 6 shillings per ton of rails as against the total royalty charges in Belgium of not more than 1*s.* 2*d.* To take a ton of these rails from Leeds to London costs 11*s.* 10*d.* Total royalty and railway rate, 17*s.* 10*d.* The Belgian firm can deliver their rails in London for 5*s.* per ton-carriage. This leaves a balance in favor of the Belgian firm of 11*s.* 8*d.* per ton in cost of carriage and mining royalties.

While other nations are going ahead by leaps and bounds in iron manufacture, Great Britain is standing still, — fettered by a load of rents and royalties such as is not tolerated in any other country. Surely, then, it is high time to draw attention in unmistakably plain language to this aspect of the problem of foreign competition, — to this antiquated land monopoly which is slowly, but none the less surely, undermining the very foundations of the British iron industry.

OPEN-HEARTH FURNACE COMPARISONS *

By A. D. WILLIAMS, Jr.

THE proportions of open-hearth furnaces are usually arrived at by an empirical ratio with their normal capacity in tons of steel produced per heat. While it would be feasible to construct rational formulas for proportioning the various parts of the furnace, the labor involved in using such formulas would consume a great deal of time and the results would be no more accurate than those arrived at by the empirical ratios used. Past experience alone will enable the designer to predict fuel consumption and output within limits when the furnace is used for the line of work for which it was designed, but radical changes in the charge and the method of working will produce corresponding changes in the output and fuel consumption.

Improvements came Slowly

For a long time furnaces were built without any consideration of the local conditions. A furnace was merely an assemblage of brick and buckstays. In many cases an ill-considered design was copied by the aid of a bricklayer, and while such a furnace turned out steel the fuel consumption was high, as were the other expenses of operation. The modern furnace builders are studying the problems to be met, stimulated to a degree by the progress made in this line abroad, particularly in Germany, where small plants are the rule and rapid production is sought after.

One of the first improvements made was in raising the roof of the furnace, thereby increasing the size of the combustion chamber and utilizing the radiant heat of the flame and at the same time reducing the tendency of the roof to collapse at unpropitious moments. The low roof sloping downward toward the center of the hearth was designed to throw the flame directly upon the charge, but it left very little room for the flame at the beginning of a heat, and the natural result followed, which was that the roof cut rapidly and ultimately collapsed. Additional material added to the outside of the roof did not help matters, and, finally, the lesson was learned that a thin roof with a suffi-

* "The Iron Age," September 21, 1905.

cient amount of room beneath it to pass the flame not only lasted longer but improved the action of the furnace.

Furnace Proportions

The early furnaces were small, and when the larger size furnaces were designed, the proportions used in smaller furnaces were often followed without much consideration being paid to all the elements which should have been considered. The area of the hearth was settled on the basis of a certain number of square feet per ton and its length was made twice the width. The volume of gas burned in a furnace is increased very nearly in direct proportion to its capacity, and an addition to the length is of more value than increased width, in that it allows a longer time for the chemical combinations of combustion to occur. The result is that the fuel is used to better advantage and less of it is required. The following table gives the hearth dimensions for a few furnaces and the ratio between hearth area and capacity and the length and width:

No.	Location	Normal Capacity. Tons	Length × Width. Feet	Hearth Area. Square Feet	Per Ton	Length divided by Width
1	Pencoyd	70	30.00 × 9.00	270	3.86	3.33
2	Frodingham	100	32.00 × 12.00	400	4.00	2.67
3	Jones & Laughlin	200	40.00 × 16.00	640	3.20	2.50
4	Pa. Steel Company	50	32.00 × 10.00	320	6.40	3.20
5	Donawitz	30	27.00 × 10.00	270	9.00	2.70
6	Duquesne	50	27.00 × 14.00	378	7.56	1.93
7	Sharon	50	29.00 × 14.50	420	8.40	2.00
8	Ill. Steel Company	35	21.87 × 12.25	267	7.62	1.79
9	Ill. Steel Company	50	32.00 × 14.00	448	8.96	2.29
10	Wellman-Seaver	50	33.67 × 13.00	438	8.76	2.59
11	Wellman-Seaver	25	25.00 × 10.50	262	10.50	2.38
12	Shoenberger	35	24.00 × 12.00	288	8.23	2.00
13	Rechitza	10	13.50 × 7.54	101	10.12	1.82
14	Barrow	50	28.00 × 10.25	287	5.74	2.73
15	Unknown	50	29.00 × 15.00	435	8.70	1.93
16	Laughlin	50	30.00 × 15.00	450	9.00	2.00
17	Homestead	40	26.33 × 12.50	329	8.23	2.11
18	Pottsville	40	24.00 × 12.00	288	7.20	2.00

The first three furnaces are used for the Talbot process. No. 17, the Homestead furnace, is used for the Monell process. The widths given for Nos. 3 and 4 are the average widths, these

furnaces being wider at the middle of the hearth and tapering toward both ends.

A cubic foot of molten steel weighs 430 pounds, and a ton occupies about 5.25 cubic feet. From this it can be seen that the average depth of the bath in the above furnaces will be from 6 to 20 inches. In the Barrow furnace, No. 14, the depth of the bath averages about 13 inches and the maximum depth is 26 inches.

Omitting the first three furnaces, which were designed for the Talbot process, in which a deep bath is necessary and only a fraction of the contents of the furnace are drawn off at a time, the above table can be summarized as follows:

Square feet of hearth pert on	Maximum	10.50
	Minimum	5.74
	Average	8.29
Ratio of hearth length to width	Maximum	3.20
	Minimum	1.79
	Average	2.23

Most of the American furnaces run under 15 heats per week of approximately 135 hours. Occasionally as many as 23 heats have been made, but such records are exceptional and not sustained. In Europe furnaces making 23 heats per week do so in regular practice and keep it up, but according to American standards these furnaces are operated under their capacity — that is, there is a great deal more furnace used to produce a ton of steel.

A Limit to the Width

In building open-hearth furnaces there is a limit to the width of hearth practicable, owing to the limit to the strength of the skew backs and the arch brick adjacent. It is also more trouble to make and patch the bottom in a wide furnace than it is in a narrow one. A long furnace with the usual arrangement means a considerable addition to the length of the building required to house the plant. The building is usually designed to suit a certain furnace, and radical changes in an existing plant are difficult to make owing to the surroundings, building columns, etc.

Proportioning the Regenerator Capacity

While the hearth area has a certain effect on the rapidity with which the furnace works, the regenerator capacity must be

so proportioned that the gas and air are at a proper heat on reaching the ports so that they will combine without withdrawing heat from the furnace. The height is really the most important of the checker dimensions, as when the volume is the same the higher checker will give better results than the lower. A great many open-hearth plants are built on the banks of rivers, where the general level of the plant is too close to the ground water line to permit of the construction of vertical checkers, and the horizontal system, which is not desirable, has been used.

The following table gives the dimensions of the portion of the regenerator chamber occupied by the checker brick in a few of the furnaces cited in the preceding table. The number refers to the preceding table, and the capacity of the furnace has been repeated to avoid referring back:

No.	Capacity. Tons		Length × Width × Height	Area, Square Feet	Area divided by Tons	Volume Cubic Feet	Volume divided by Tons	Air divided by Gas
6	50	Air,	22.00 × 10.00 × 9.00	220	4.40	1,980	39.80	
		Gas,	22.00 × 6.00 × 9.00	132	2.64	1,188	23.78	
				352	7.04	3,168	63.58	1.67
8	35	Air,	12.17 × 8.33 × 8.50	101	2.89	859	24.60	
		Gas,	12.17 × 6.33 × 8.50	77	2.20	655	18.72	
				178	5.09	1,514	43.32	1.31
9	50	Air,	22.00 × 10.83 × 10.50	238	4.76	2,499	49.98	
		Gas,	22.00 × 7.92 × 10.50	174	3.48	1,827	36.54	
				412	8.24	4,326	86.52	1.36
10	50	Air,	23.50 × 8.00 × 10.00	188	3.76	1,880	37.60	
		Gas,	23.50 × 5.50 × 10.00	129	2.58	1,290	25.80	
				317	6.34	3,170	63.40	1.46
11	25	Air,	18.00 × 6.00 × 8.50	108	4.32	918	36.72	
		Gas,	18.00 × 4.50 × 8.50	81	3.24	688	27.52	
				189	7.56	1,606	64.24	1.325
14	50	Air,	12.25 × 9.50 × 9.25	116	2.32	1,075	20.15	
		Gas,	12.25 × 9.50 × 9.25	116	2.32	1,075	20.15	
				232	4.64	2,150	40.30	1.00
15	50	Air,	18.00 × 12.00 × 14.50	216	4.32	3,132	62.64	
		Gas,	18.00 × 8.00 × 14.50	144	2.88	2,068	41.36	
				360	7.20	5,200	104.00	1.52
16	50	Air,	18.17 × 12.08 × 14.00	219	4.38	3,066	61.32	
		Gas,	18.17 × 10.08 × 14.00	183	3.66	2,562	51.24	
				402	8.04	5,628	112.56	1.195

For each furnace the third line gives the ratio for the combined sum of the gas and air regenerators. No. 6 is fired with natural gas, but is arranged to use producer gas if necessary. Nos. 8, 9, 10, 11 and 14 are fired with producer gas. Furnace No. 16 somewhat closely approaches foreign practice both in its regenerators and hearth.

In some foreign furnaces the total volume of the regenerators is 4 cubic meters, or 140 cubic feet, per ton, half of which is in the gas and half in the air checkers. A more usual method is to make the air regenerators 10 per cent greater in volume than the gas regenerators, giving 74 cubic feet to the air and 67 cubic feet to the gas checkers per ton, and in a few cases even larger regenerators are in use. Another ratio used abroad is to allow from 110 to 155 pounds of checker brick per pound of coal burned in the producers per ton of steel. One brick weighs 7.33 pounds, and when set $3\frac{1}{2}$ inches apart, which is the usual gauge for checker brick, the above ratio would mean a checker volume of 105 to 150 cubic feet per ton, with a fuel consumption of 500 pounds of coal to be divided between the gas and the air.

In modern furnaces the regenerators are placed beneath the charging platform and a good sized cinder pocket is provided, which catches the cinder carried over and prevents the checkers from becoming bunged up and destroyed. The early furnaces were supported on the regenerator casings and a great deal of trouble was due to such construction, as this brick work was continually expanding and contracting, racking the pan and causing cracks in the bottom. Fortunately, in most cases these cracks amounted to little, but whenever it was necessary to rip out an old bottom it was found full of threads of steel, which in many cases had reached the pan and chilled there without causing a run out. Modern furnaces are supported independently of the flues leading to them, steel columns and beams being used, upon which the pan rests, or in some cases a solid mass of brick and concrete is used without a pan.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

THE Thermal Transformations of Carbon Steels. J. O. Arnold and Andrew McWilliam. The Iron and Steel Institute, September, 1905, meeting. 11,000 w., illustrated. — The authors determined the thermal critical points of three samples of steel, containing respectively 0.89, 0.21 and 1.78 per cent carbon and small amounts of impurities, and studied the corresponding structural changes. The accompanying diagram represents their interpretation of the nature and transformation of pearlite. The authors conclude as follows:



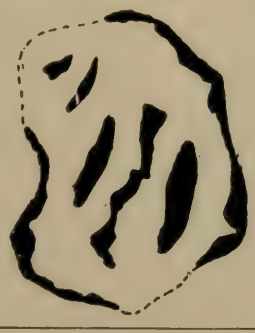
J. O. Arnold

" 1. The cooling transformations of an unsaturated iron and carbon steel, previously heated to about 950° C., when studied under suitable thermal conditions on a steel in which the points Ar_3, Ar_2 and Ar_1 can be clearly differentiated, lead to the following conclusions: Above Ar_3 (*i. e.*, 810° C.), the ferrite and hardenite are in mutual solution as a homogeneous mass. The Ar_3

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When ordering, both the number and name of the abstract should be mentioned.

Showing the Properties of Pearlite and its Decomposition Product. Fe_3C represented Black.

Mechanical Properties of Mass.	Microstructure.	Segregation Stages.
Maximum tensile stress about 70 tons per square inch. Elongation on 2 inches = about 10 per cent.		1ST PHASE. "Sorbitic" pearlite with emulsified Fe_3C. Very dark on etching.
Maximum tensile stress about 55 tons per square inch.. Elongation on 2 inches = about 15 per cent.		2ND PHASE. Normal pearlite with semi-segregated Fe_3C. Dark on etching.
Maximum tensile stress about 35 tons per square inch. Elongation on 2 inches = about 5 per cent.		3RD PHASE. Laminated pearlite with completely segregated Fe_3C. Exhibiting a play of gorgeous colours when lightly etched.
Maximum tensile stress about 30 tons per square inch.		4TH PHASE. Laminated pearlite passing into massive Fe_3C and ferrite.

NOTE.—It is important to remember that in a single section of steel two or even all three phases of pearlite may be observed in juxtaposition gradually merging into each other.

change is accompanied by a segregation of the two constituents, which, if the cooling be slow, is probably completed in the Beta range of temperature. On reference to Micrograph No. 4 it will be seen that after a fairly rapid cooling from 950° C. the 0.21 per cent carbon steel, when quenched at 730° C. (or near the middle of the point Ar_2), micrographically registered a segregation of ferrite so far advanced as strongly to suggest that such segregation must have begun at Ar_3 and not as Ar_2. In other words, hardenite is insoluble in ferrite in both the Beta and Alpha ranges of temperature. It, however, still retains its identity as hardenite whilst falling through, say, 30° or 40° C. of temperature in the Alpha range — namely, from the end of Ar_2 at about 720° C. to the beginning of Ar_1 at about 680° C., at which latter temperature it begins to decompose into pearlite.

" 2. The heating transformations of the above steel are substantially as follows: At Ac_1 (about 710° C.) in the Alpha range the pearlite begins to change into hardenite; hence the Beta carbide is soluble in the Alpha range. The change to hardenite is somewhat advanced when Ac_1 merges into Ac_2 at about 720° C., owing to these points always overlapping in the heating curve. The hardenite areas probably remain unchanged on the sites previously occupied by the pearlite till the Gamma range Ac_3 is reached (at about 810° C.), when the hardenite and ferrite dissolve into each other, forming a homogeneous molecular mixture.

" 3. In a saturated steel there is, on heating, a single absorption of heat at the change point $Ac_{1,2,3}$, the amplitude of which ranges from about 710° C. to 730° C. This change marks the transformation of the whole mass from pearlite into hardenite.

" 4. On cooling, there is a very considerable evolution of heat at the single point $Ar_{1,2,3}$, the amplitude of which ranges from about 690° to 660° C. This recalescence marks the transformation of hardenite into pearlite. The particular phase of pearlite obtained depends upon the rate of cooling from 660° C. to atmospheric temperature. The emulsified phase is produced by very rapid cooling, normal pearlite by ordinary cooling and laminated pearlite by very slow cooling. Pearlite, in which the carbide is emulsified or ' sorbitic,' may also be produced by tempering hardenite.

" 5. The micrographic and thermal transformations of a

supersaturated steel are as follows: At $Ac_{1,2,3}$, the sectional ground mass pearlite changes to hardenite, the cementite slowly segregates into larger masses until a temperature of about 900° C. is reached, then the cementite and hardenite dissolve one into the other and a homogeneous mass of hardenite and cementite is obtained.

"6. On cooling, at about 900° C. the cementite falls out with a faint evolution of heat and is completely segregated long before the point $Ar_{1,2,3}$ is reached; hence the micrographic transformations of cementite and hardenite are quite unconnected with the three thermal critical points or any of them and are due entirely to the influence of temperature." **No. 434.**

The Cleaning and Agglomerating of Ore Dust. "The Iron Trade Review," September 14, 1905. 2,600 w., illustrated. —Description of the plant of the Ruthenberg Reduction Company, at Niagara Falls, N. Y., for the separation of impurities from fine ores by magnetic action and the concentration of ore dust for the blast furnace by an electric process.

To bring the ore dust into condition for practical use in the blast furnace it must be converted into a shape which will permit the gases of the furnace to percolate through the charge and so must be of some size and weight. The product of the Ruthenburg process is in the form of bean-like particles, and constitutes an admirable form for use in the ironmaker. The contrast in the physical structure of the concentrates before and after agglomeration is shown by the accompanying reproduction from a photograph of an equal weight of concentrates through a 20-mesh sieve and the Ruthenburg product.

To convert the concentrated dust, a tower which is similar in appearance to a blast furnace cut off above the tuyères, has been erected and also constructed to provide for the reduction of the ore at the same time, which is the third step in Mr. Ruthenburg's scheme. The tower, a sectional view of which, together with the gas producer for reducing the ore, is shown, is about thirty feet high and about thirteen feet in diameter at the base, and built of brick. In the interior is an inner tower, between the outside wall and which is an annular space, the purpose of which will be shown later.

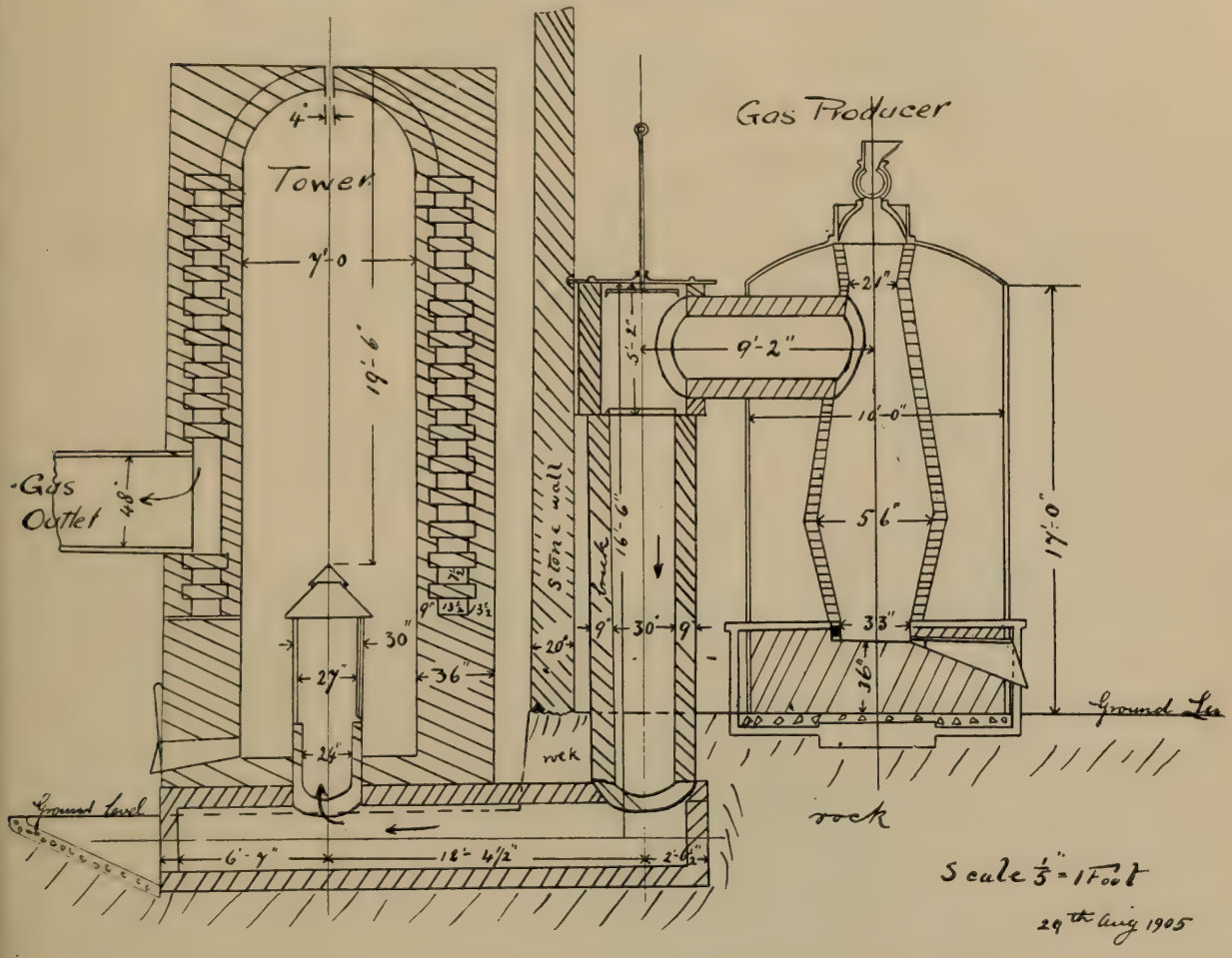
On top, over the mouth of the tower, is placed an electric

furnace of Mr. Ruthenburg's design. The only inlet for charging the dust into the tower is between the arms of the furnace, which are electrically insulated from each other and form the terminals of a heavy melting circuit.

Current is supplied to the coils, and the two arms between which the ore dust must pass into the tower are strongly magnetized. The dust is raised on an elevator which stands at one side of the tower and fed directly on the two magnetic arms of the furnace, assuming a condition as shown.

The resistance to the passage of the melting current, set up by the finely divided particles of ore, which form a magnetic bridge and an electrical resistance, heats them to the point of fusion and melted globules and masses of the ore drop to the bottom of the tower in a small and fairly uniform size, which regularity is contributed to by the falling of the molten particles through the distance from the top of the tower to the level of the charge. This melting is continued at the rate of about 2,000 pounds per hour, using 165 kilowatts in that time, which means, for the rate at which electric power is supplied at Niagara, a cost of about fifty cents per ton. The tower is filled up and then the process of reduction begins, the feeding of dust and the drawing off of reduced metal sponge being continuous. In an adjoining room, a hermetically sealed steel gas producer has been erected for making producer gas. The object in hermetically sealing is to enable the gas pressure, necessary to force gas through the material in the tower, to be obtained by sending air into the producer under pressure. To obtain a pressure of five pounds, which is the blast used, the company has installed a Connersville air blower driven by a three-phase alternating current motor. The charge of coke is admitted through a device at the top consisting of a rotating barrel with two slots less than 180 degrees apart. The charge is placed in the barrel, which is then rotated, the charge falling into the producer as the second valve opens downward, the charging valve then being closed so that no gas escapes. The ashes are taken care of by fluxing with blast-furnace slag. The hot gas under pressure passes through the main containing a sand valve into the bottom of the agglomerating tower where it forces its way up through the ore. In the absence of the air the ore is reduced by the gas, which, in turn, is converted in part

into carbon dioxide and on reaching the top burns in contact with air and is diverted downward into the annular space surrounding the inner tower, thus aiding in maintaining the heat of the ore. The gas is exhausted near the bottom of the tower into the open air through a chimney. From the time that any given part of the ore is charged into the tower until it reaches the bottom and is ready to be drawn out as wrought iron through ports provided, about twenty-four hours elapse. The sulphur



in the ore is eliminated in the furnace during the fusion of the dust, when the following reaction takes place: $2Fe_3O_4 + 4FeS = 5Fe_2 + 4SO_2$. Concentrates with as much as 0.8 per cent of sulphur give an agglomerated product with 0.03 per cent sulphur. The SO_2 gas can be readily seen coming from the furnace at the top of the tower, and as there is no sulphur in the producer gas the iron taken from the bottom of the tower is practically free from that impurity. **No. 435. A.**

The York Process for Rolling Steel Ties from Old Rails. "The Railroad Gazette," November 24, 1905. 2,000 w., illus-



FIG. 1.

trated. — The York process of rolling is a radical departure from any previous rolling-mill practice and enables almost any desired



FIG. 2.

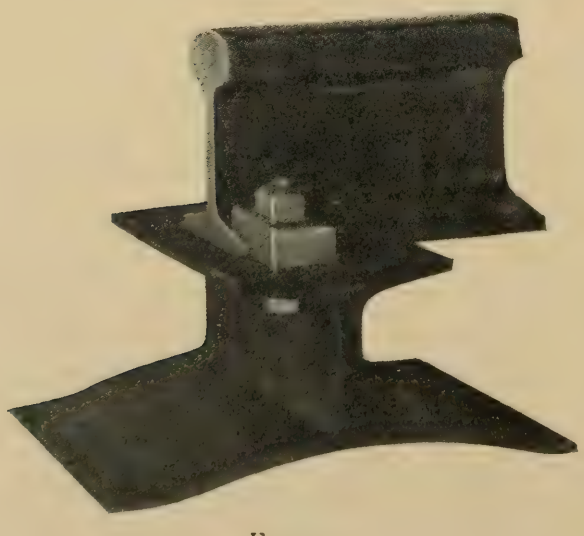


FIG. 3.

section to be made from either the head or bottom flange, no matter how badly worn or unsymmetrical the scrap stock may be. Fig. 1 shows a few of the many structural shapes which can be rolled from the rail shown on the left. Figs. 2 and 3 show the forms of ties which may be rolled, one with a flat bottom and the other

with a concave bottom, giving the tie itself elasticity in the ballast under heavy loads. **No. 436. A.**

The Kjellin Electric Steel Furnace. "The Iron Age," October 19, 1905. 5,000 w., illustrated. — A description of the construction and operation of the Kjellin Electric Steel Furnace, with special reference to the steel works at Gysinge, Sweden. **No. 437. A.**

Fortschritte im Bau von Gasofen für Eisenhuttenwerke (Improvements in the Construction of Gas Furnaces Used in Steel Works). A. Desgraz. 3,000 w. "Stahl und Eisen," July 1, 1905. **No. 438. D.**

Die Herdofenstahlerzeugung aus Flüssigem Roheisen (The Open-Hearth Process for the Production of Steel from Cast Iron). Oskar Simmersbach. "Stahl und Eisen," June 15 and July 1, 1905. 3,800 w. — The author describes the growth of the open-hearth process, comparing it to that of the Bessemer process. **No. 439. D.**

Experimentelle Studien über die Vorgänge im Hochofen (Experimental Studies of the Reactions in the Blast Furnace). F. Zimmermann. "Stahl und Eisen," July 1, 1905. 2,000 w. — The author discusses the reactions taking place in the blast furnace as indicated chiefly from the composition of the gases taken from various zones of the furnace. **No. 440. D.**

The Presence of Greenish-Colored Markings in the Fractured Surfaces of Test Pieces. H. C. Howarth. Iron and Steel Institute, September, 1905. 7,000 w., illustrated. **No. 441.**

Wear of Steel Rails on Bridges. Thomas Andrews, Iron and Steel Institute, September, 1905. 10,000 w., illustrated. **No. 442.**

Experimental Desulphurization. Reginald Meeks. "The Iron Age," November 9, 1905. 2,000 w. — The author describes some attempts to reduce the percentage of sulphur in cast iron (1) by the addition of much limestone to the charge; (2) by the use of manganese ore and (3) by the addition of ferro-manganese in the cupola or in the ladle. The first two methods were found ineffective, while the use of ferro-manganese resulted in a marked decrease of the sulphur content. **No. 443. A.**

METALLURGICAL NOTES AND COMMENTS

Standard Method for the Determination of Silicon in Cast Iron. — At the annual convention of the American Foundrymen's Association held in New York City, June 6 to 8, the following report of the metallurgical section read by H. F. Dilles, secretary, was submitted and duly adopted:

" During the past year your committee has formulated a method for determinating the silicon in cast iron, and is now at work on the question of the total carbon. The following is the method which your committee recommends to be the standard of the association, for the determination of silicon in pig iron and cast iron:

" ' Weigh one gram of sample, add 30 cc. nitric acid (1.13 sp. gr.); then 5 cc. sulphuric acid (conc.). Evaporate on hot plate until all fumes are driven off. Take up in water and boil until all ferrous sulphate is dissolved. Filter on an ashless filter, with or without suction pump, using a cone. Wash once with hot water, once with hydrochloric acid, and three or four times with hot water. Ignite, weigh and evaporate with a few drops of sulphuric acid and 4 or 5 cc. of hydrofluoric acid. Ignite slowly and weigh. Multiply the difference in weight by 0.4702.'

" In recommending the above method, it was recognized that it is almost an impossibility to get chemists to use a standard method in their daily work. Hence the above method, as recommended, is intended primarily as a check method in case of dispute between different laboratories, or as between buyer and seller.

" Hence a method accurate in every point was sought, shortness being sacrificed to some extent to insure accuracy or the chance of error by a careless operator. Little in the above is left to the judgment of the chemist.

" It will be further recognized that in the purchase and sale of pig iron or castings under specification, that standard methods are essential in order to allow the parties of both parts to make

their determinations with the assurance that, on the score of method, they are on the same footing."

A New Method of Preventing Pipes in Large Ingots.* — In the manufacture of large steel ingots for forgings or other purposes it is often necessary to allow for a discard as high as 25 or 30 per cent of the total weight on account of the " pipe " formed as the metal contracts in cooling. The use of a sink head lined

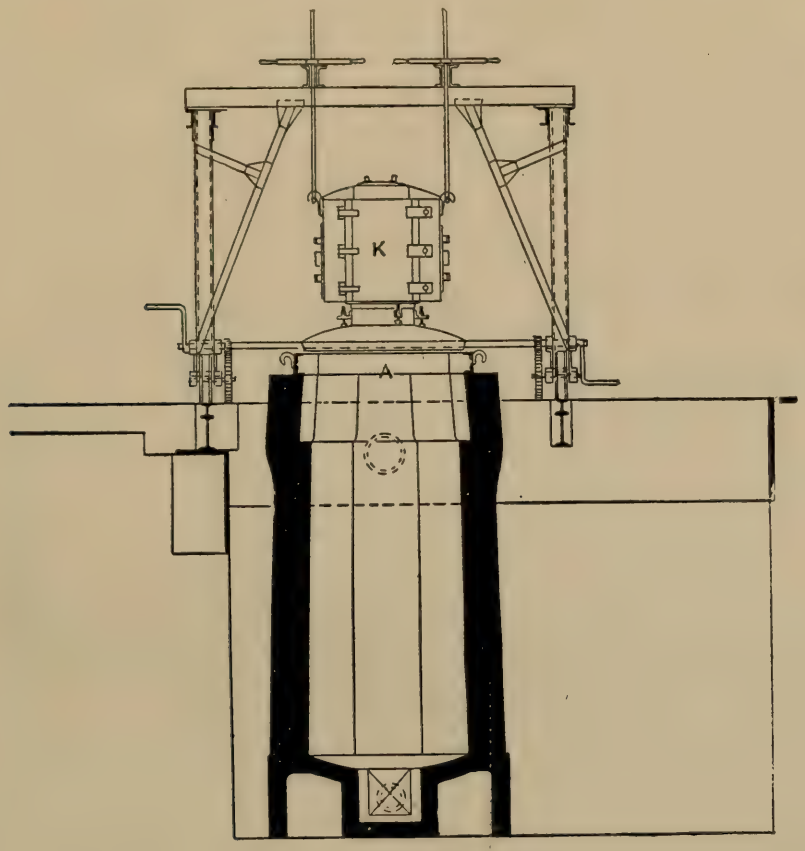


FIG. 1. End Elevation

with fire clay or other refractory material, for the purpose of keeping the top of the ingot longer molten, is successful to a certain extent and results in a shorter pipe, but does not altogether eliminate the piping. Covering the molten metal with charcoal or similar material has the great disadvantage that a considerable carburization of the upper third of the ingot often

* From F. O. Beikirch, in " Stahl und Eisen." " Iron Age," October 5, 1905.

results, while if slag or sand is used a portion is often drawn into the interior. The use of hydraulic pressure to compress the steel while passing from the molten to the solid state has the desired effect, but the cost of installing and operating machinery for this purpose is in most cases prohibitive.

The process here described, which in most countries is protected by patents, has been in use for a year at the Gutehoff-

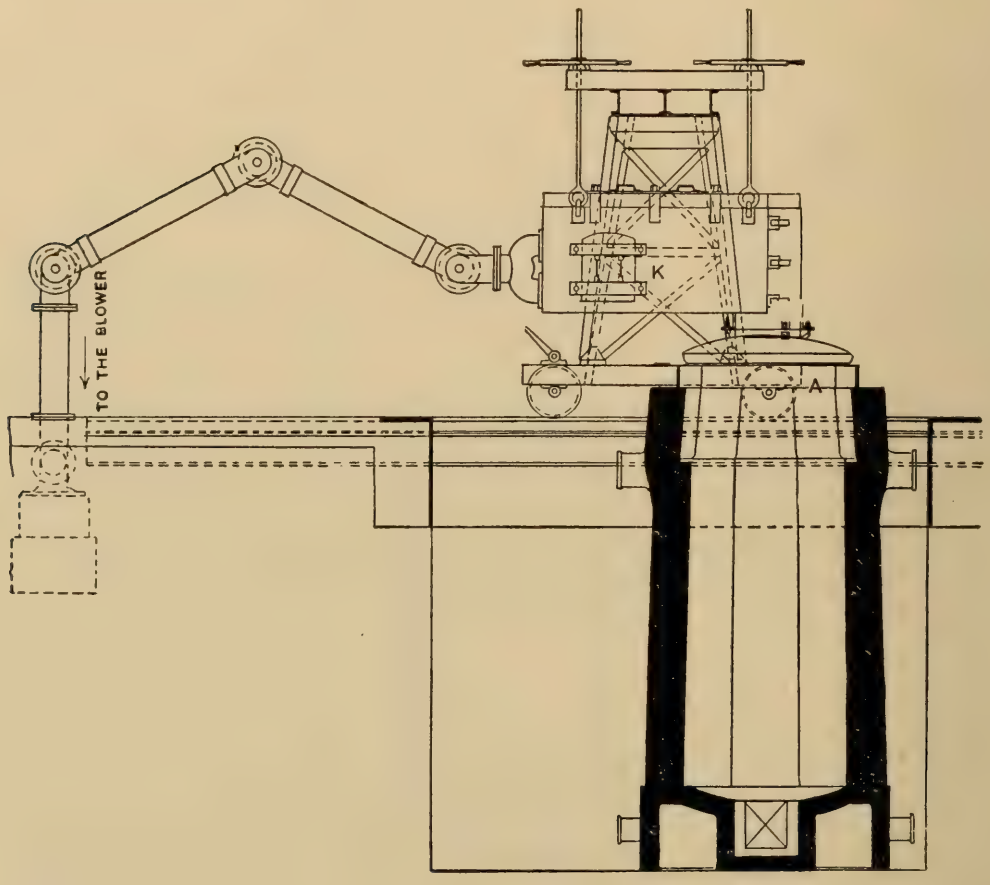


FIG. 2. Side Elevation

nungs Works in Oberhausen, Germany, giving good results on ingots up to 60 tons weight. It is based on the theory that external heat is necessary to keep the steel in the sink head molten until the ingot is solidified and all danger of piping has passed. This heat is obtained by blowing cold air through incandescent coke, so regulating the pressure that in the fuel chamber only carbon monoxide is formed, combustion to carbonic acid being completed in the space above the sink head.

The original article reproduces photographs of four ingots cast by this method, which show almost complete freedom from pipes. The weight and amount of discard necessary with each of these ingots were as follows: No. 1, weight 11.6 gross tons, discard 7.3 per cent; No. 2, weight 17 tons, discard 4.98 per cent; No. 3, weight 17.2 tons, discard 5.52 per cent; No. 4, weight 16.4 tons, discard 3.6 per cent.

The accompanying illustrations show the arrangement for ingots from 10 to 60 tons. Fig. 1 is an end elevation, Fig. 2 a side elevation and Fig. 3 the plan. The method of operating is as follows: The chamber K is filled to the top with pieces of hard coke about the size of a man's fist. About an hour before the ingot is poured the fuel is brought to redness by means of a

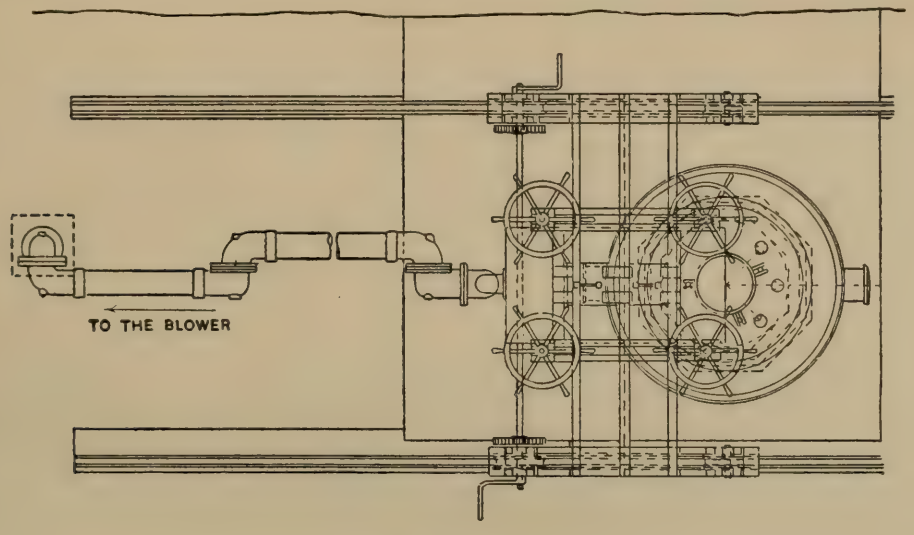


FIG. 3. Plan

gentle blast, the flame which escapes at A being used to warm the mold and more particularly the refractory lining of the head. Shortly before the steel is poured the apparatus is drawn back out of the way and at the same time the full pressure of blast is put on, so that by the time the mold is full, in fifteen to twenty-five minutes, the fuel is at a bright red heat, ready to be replaced over the mold. As may be seen from the illustrations, the apparatus is placed on a carriage, which can quickly and easily be moved forward or back. As cold blast is used the blower can be placed close to the casting pit, so that the whole arrangement is very simple and compact.

Iron Ore Analysis at Lake Superior Mines.* — The idea of compiling the methods used in the laboratories of the iron mining companies of the Lake Superior district in the analysis of iron ores was suggested by the work of Francis G. Phillips on "Methods for the Analysis of Ores, Pig Iron and Steel," published by the Engineers' Society of Western Pennsylvania, 1896, and later in book form by the Chemical Publishing Company. The plan therein carried out has been followed in the present inquiry. A letter was addressed to each of the chemists whose name and address the writer was able to obtain, requesting a description of the methods used in the analysis of iron ores in the determination of iron, phosphorus and such other substances as might be determined. The responses were quite general, but few of those addressed failing to send in a description of the methods employed.

The intention is not to present a scientific treatise on iron ore analysis, but to set forth in some detail the methods of procedure carried out in the daily work in the analysis of iron ores, which furnishes the basis for the grading of the ores and the commercial transactions of the mining companies. Because of the limited time allowable for analyses, and the accuracy and reliability that results must present, we believe that in the Lake Superior district the methods employed are as rapid and at the same time as reliable as may be found in use in any section in the commercial analysis of iron ores. That the present compilation is in many respects crude and imperfect we are well aware. The attempt was made to reach all the chemists of the region and the desire was to give all an opportunity to contribute to the work. No doubt some may have been missed.

The reports coming from the chemists of the different mining sections are distributed as follows: From Minnesota five, representing the Vermilion and Mesaba ranges; from the Gogebic range six, from the Menominee range five, from the Crystal Falls district two, from Marquette County three, from the Baraboo district, Wisconsin, two, and from Ontario one. Total, 24.

Two methods are in general use in the determination of iron. The permanganate method, familiar to most of us, is used by seventeen chemists; the other, the bichromate method, by but seven.

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* A paper read by W. A. Siebenthal before the Lake Superior Mining Institute, Iron Mountain, Mich., meeting, October, 1905.

Three Methods for Phosphorus

In the determination of phosphorus three general methods are described with varying modifications in manipulation. One, the Handy alkalimetric method, in which the phosphorus is precipitated as yellow ammonium phosphomolybdate dissolved in standard sodium hydrate and titrated with standard nitric acid, is used by twenty of the chemists. The Emmerton method, in which the yellow precipitate is dissolved in ammonium hydrate, reduced with zinc and sulphuric acid and titrated with potassium permanganate, is used by three; and a modification of the Wood method, described in Blair's "Chemical Analysis of Iron," in which the phosphorus is determined gravimetrically by weighing the yellow ammonium phosphomolybdate precipitate, is used by one of the chemists. In some instances two methods are reported by some of the chemists.

Two methods of more than the usual rapidity are described, one by John McNamara of Ironwood, the other by F. A. Janson, of Vulcan, Mich., both being modifications of the Handy method.

In the determination of silica two methods are described. The sodium carbonate fusion method is used by seven; the hydrofluoric acid method by four. Both are used by some of the chemists.

Volhard's method for manganese, with various modifications, is used by fourteen of the chemists; Julien's method by one, and a gravimetric process is described by one.

Of those reporting methods for the determination of calcium, ten use a gravimetric method, precipitating the calcium as calcium oxalate, igniting and weighing as calcium oxide (CaO). One uses a volumetric process, titrating with potassium permanganate.

Magnesia is determined gravimetrically as magnesia pyrophosphate by six, and alumina as aluminum phosphate by nine of the chemists who report methods for such determinations.

Sulphur is determined as barium sulphate by those reporting on the determination.

One chemist describes a method for the determination of titanium.

Methods for moisture determination are described by four, and for organic and volatile matter by three chemists.

The Value of Comparisons

The interest and value of this collation of methods to the chemists of the district, it seems to me, is to be obtained from the differences in details and manipulation as well as in the general differences of methods. Already I have found myself making some changes in my own work, applying some of the details given by some of the chemists in their descriptions.

In conclusion, while some of the methods described may be as rapid and reliable as any in general use, it seems to me that there is a possibility for improvement and an excellent opportunity for research along the line of both shortening and simplifying some of the methods given, especially in the determination of phosphorus. A method for the direct oxidation and dissolving of the phosphorus without the complete solution of the ore would greatly simplify the process.

The two methods given for the determination of iron are quite simple when compared with those described for other substances; yet each has certain objections — the permanganate method, because of the inconstancy of strength of the solution; the bichromate method, because it is slower and requires the use of an external indicator.

An internal indicator would be a decided improvement in the bichromate method. Keeping the permanganate solution under some gas rather than in contact with the air might remedy the objection to the permanganate method.

Phosphides and Carbides in Iron.* — At the opening meeting of the session 1905–6, held in the Department of Applied Science at Sheffield University on the 25th inst., Mr. J. E. Stead, in the course of a lecture on "The Behavior of Phosphides and Carbides when together in Iron," described the micro-structure and mechanical properties of a series of steels containing 0.04 per cent, 0.30 per cent and 0.50 per cent phosphorus and 0.30 per cent carbon, showing that the most phosphorized portions were concentrated at the junction of the primary crystals, and that these junctions are always free from carbon in the annealed material. A comparison of the results of testing by various methods led to the interesting conclusion that ordinary tensile

* "The Iron and Coal Trades Review," November 3, 1905.

testing was not sufficient to indicate "phosphorus brittleness," and that Professor Arnold's vibratory strain tests indicated an increasing brittleness with each increment of phosphorus. Mr. Stead described the method of slightly bending small strips of steel backwards and forwards till they broke, by which means results closely corresponding to those of Professor Arnold were obtained. The most remarkable results were those given by testing the steels in a fiber stress machine of the Wohler type, under a constant rotary stress of 25 tons. The resistances to this true fatigue test for the three cases were in the ratio of 1, 2.7 and 10. The steel with 0.5 per cent phosphorus stood ten times as much fatigue as the steel with 0.04 per cent of that element. Why this was so was explained by the evidence given by the tension tests, which showed that each 0.1 per cent phosphorus had raised the yield point and tenacity by about 2.5 tons per square inch. It was not to be supposed that he advocated high phosphorus steels. The ingots he had used were only 6-inch cubes; had they been of the usual size employed in steel works the results would have been quite different, due to excessive segregation of the phosphorus into local positions. The lecturer went on to explain what occurred when steel solidified in the ingot mold, and proved the existence of three distinct modes of segregation: First, the microscopic in the body of the crystal itself; second, the minor segregations which were entangled at the junctions of the crystallites; third, the major or axial segregation well-known to all steel makers. The lecturer suggested that if large ingots of fluid steel were revolved on their axes during the cooling period, probably "ghost" lines would not appear in the forging, or if they did they would be very small, the reason for this belief being that motion of the fluid steel would tend to the production of small entanglements of the segregated portions, whereas illustrations were given showing that sometimes the crystals in very large ingots were as much as 7 inches in length.

The Harvey Steel Royalty Cases.* — By a judgment just handed down by the Court of Claims, the Carnegie Steel Company has been awarded $8,024.45 for royalties paid to the Harvey Steel Company for the use of the so-called Harvey process for

* "The Iron Age," November 23, 1905.

face hardening armor. This process was employed by the Carnegie Company under the terms of a contract with the United States in which it was agreed that the government should pay all royalties, but which it subsequently refused to do.

The Harvey process of hardening armor plate was employed by the Ordnance Bureau of the Navy Department for a number of years on a royalty basis. The government finally refused to pay royalties and withheld a considerable sum from the patentees on the ground that the patent was invalid, although it was conceded that the process was efficient and was necessary to the manufacture of plates possessing the highest ballistic resistance. The Harvey Steel Company, the owners of the process, then began an action in the Court of Claims to recover $60,806.45 alleged to be due in the form of moneys withheld under contracts with the Navy Department. The Court of Claims recently decided this case adversely to the government, on the ground that after having employed the process and having received from the Harvey Steel Company all the information necessary to produce the best armor plate known to the art, it could not claim not to have received full consideration for the payments promised under the contract. In conclusion, the court laid down a proposition having a broad bearing upon patent litigation in which the question of the validity of a patent is involved in a claim for royalties, saying:

"In a word, this is a case where a man without fraud or misrepresentation entered into a contract; where he received from the other party all that the contract promised him or that he expected to receive; where he kept his mouth closed when he should have spoken and withheld the defense when he should have interposed it; where by his silence and his words he misled the other contracting party and thereby deprived him of his legal right to the adjudication of courts of competent jurisdiction, which adjudication might be favorable to the other party and cost irreparable loss and injury to himself. Such a man is not entitled to set up in an action on the contract the defenses which the defendant's executive officers have insisted on interposing in this case. The court has not entered into an examination of the patent; of the construction which should be given it; of the state of the art or of any of those questions which would properly be subjects of consideration if this were an action for

infringement." The court thereupon gave judgment for the entire sum claimed.

In addition to this suit of the Harvey Steel Company against the United States, the Carnegie Steel Company began an action for $8,024.45 on account of royalties paid the Harvey Steel Company for the use of its process in the manufacture of armor for the government. Before this case was taken under consideration by the Court of Claims the United States Supreme Court rendered a decision sustaining the court below in the case of the Harvey Steel Company *v.* United States. The Court of Claims therefore promptly gave judgment in favor of the Carnegie Steel Company and will certify the decision to Congress for an appropriation at the coming session.

Upon a supplemental petition filed by the Harvey Steel Company the Court of Claims has given an additional judgment against the United States for $650,132.17, being the amount of royalties that have accrued since June, 1898, and up to September 30, 1905, on the basis of the findings in the original case of the Harvey Steel Company *v.* United States above referred to.

Present Available Capacity of the Blast Furnaces of the United States.* — The annual capacity of all the blast furnaces in the United States which were active on June 1, 1904, or which were likely to be some day active, as published in our Directory in August, 1904, amounted to 28,114,000 gross tons of pig iron. Included in these figures were 8 completed furnaces, with an annual capacity of 1,155,000 tons, which had not made pig iron down to the date named but have since been blown in. Also some furnaces which would never run again but whose fate could not then be determined.

Since June 1, 1904, 15 furnaces, with a total annual capacity of 1,982,000 tons, have been completed and blown in, and 15 furnaces, with a total annual capacity of 461,000 tons, have been abandoned or dismantled. In addition, 16 furnaces, with a total annual capacity of 1,830,000 tons, were in course of erection on November 1, 1905. Full particulars concerning all completed building and abandoned furnaces will be found in

* "Bulletin," American Iron and Steel Association, December 1, 1905.

accompanying lists, which have been corrected to November 1 or to later dates.

During the period between June 1, 1904, and November 1, 1905, a number of furnaces which were classified as active on the former date have been equipped with additional blowing machinery or have been rebuilt or reconstructed, thus increasing their annual capacity, as we estimate it, at least 500,000 tons. On the other hand, a number of furnaces which were included in the active list on June 1, 1904, have since been idle and are likely to long remain idle, while others that have been idle since that date will soon resume operations. We estimate the annual capacity of these idle furnaces at approximately 1,500,000 tons. Summarizing the foregoing details we reach the following results:

Furnaces — Gross Tons	Annual Capacity
Completed furnaces on June 1, 1904	28,114,000
Completed and blown in since June 1, 1904	1,982,000
Total	30,096,000
Abandoned or dismantled since June 1, 1904	461,000
Total	29,635,000
Rebuilt and enlarged since June 1, 1904	500,000
Total	30,135,000
Furnaces idle since June 1, 1904	1,500,000
Approximate annual capacity in November, 1905	28,635,000

The 16 furnaces which were in course of erection on November 1, 1905, will have a total annual capacity of 1,830,000 tons. Of these furnaces 3 stacks, with an annual capacity of 315,000 tons, will probably be ready for blast in January, 1906; 2 stacks, with an annual capacity of 240,000 tons, will be ready in February; 2 stacks, with an annual capacity of 215,000 tons, will be ready in March; 1 stack, with an annual capacity of 145,000 tons, will be ready in April; 3 stacks, with an annual capacity of 450,000 tons, will be ready in June; and 5 stacks, with an annual capacity of 465,000 tons, will be ready in the summer or fall of 1906.

As the production of pig iron in this country in October was at the rate of almost 25,000,000 tons annually, it will be seen that, if the capacity of the furnaces which have been idle since June 1, 1904, be omitted, over 87 per cent of the available furnace capacity of the country on November 1 was then in operation.

During November several furnaces which have been idle since June, 1904, have resumed work, and repairs are now being made to a number of furnaces long idle which are expected to be ready for blast in December, January and February. If to the capacity of these furnaces we add the capacity of the building furnaces which are to be ready for blast in January and February, 1906, it will be found that within the next ninety days furnaces with an annual capacity of about 1,000,000 tons will probably be running.

The Crucible Steel Company of America.* — The fifth annual report of the stockholders of the Crucible Steel Company of America for the year ending August 31, 1905, was issued on October 6. The report is very favorable. At the close of the fiscal year, August 31, 1904, the total debt of the company was $6,203,767.06; at the close of the fiscal year, August 31, 1905, it was $3,650,189.87; showing a reduction of $2,553,577.19, including $33,000 of bonded indebtedness. During the past year the company has met all its current obligations and in addition has anticipated payment of notes covered by the collateral trust bonds to the amount of $808,000. This improvement in the company's financial condition renders it unnecessary to issue any part of the $7,000,000 bonds authorized at the last annual meeting. There are now no liens of any kind against the plants or properties of the company other than the collateral trust bonds, amounting to $1,567,000, and the mortgages, amounting to $171,932.56. The amount of these mortgages represents the purchase price of several pieces of land at Clairton, now under agreement of sale to the Clairton Steel Company.

Since the last annual statement the company has purchased the outstanding stock (about 25 per cent) of the Canton Steel Company and now owns all that company's property and assets.

A Large Steel Rail Contract.† — The Lackawanna Steel Company has been awarded the record-breaking contract for steel rails which are to be used in the construction of the Havana Central Railway Company's extensive electric traction system

* "Bulletin," American Iron and Steel Association, November 1, 1905.
† *Ibid.*, November 15, 1905.

in Cuba. The contract calls for the shipment of nearly 18,000 tons of rails, to be laid on almost 250 miles of track. This is by far the most important contract ever let in this country for trolley rails to be shipped outside the United States, although there have been a number of larger orders placed in the states for foreign steam roads, notably for the Russian, Australian and Argentina lines.

The Baldwin Locomotive Works.* — The Baldwin Locomotive Works built 225 locomotives in October last. This is the largest monthly output in the company's history. The total output this year will break all records. To build these locomotives required the employment of 16,750 men in the shops in Philadelphia alone. With the force at Burnham there are on the pay rolls of the company more than 19,000 men. The shops are kept going from midnight Sunday until midnight the following Saturday. Most of the locomotives were large freight engines. During the twenty-five working days in October nine locomotives a day were turned out.

The United States Steel Corporation.* — On October 31 the United States Steel Corporation directors declared a regular quarterly dividend of $1\frac{3}{4}$ per cent on the preferred stock. The unfilled orders on hand on September 30, 1905, aggregated 5,865,377 tons, against 4,829,655 tons on June 30, 1905, and 3,027,436 tons on September 30, 1904. The net earnings for the September quarter of 1905 were $31,240,582, an increase of $12,466,650 over the same quarter of 1904, when the earnings were $18,773,932. In the same quarter of 1903 they were $32,422,955.

Joint Meeting of the American Institute of Mining Engineers and the Iron and Steel Institute. — The following is extracted from a circular issued November 23, 1905, by the secretary of the American Institute of Mining Engineers:

"After much consultation and correspondence, the date first suggested has been changed. It is now settled that the meeting will begin in London, July 23, 1906, and will continue (including all sessions, entertainments and excursions in Great

* "Bulletin," American Iron and Steel Association, November 15, 1905.

Britain) about two weeks. No attempt will be made through this office to organize a special party for the ocean trip; but if it should hereafter appear that a sufficient number of members desire to go and return in a body, the matter will be placed in the hands of some leading tourist agency for the necessary arrangements.

"Comparatively little time will be available at this meeting for the reading and discussion of papers — not more than two or three sessions for the papers of both societies. Consequently, the following rules and suggestions are issued, by authority of the Council, for the acceptance and printing of papers, and their presentation during the time allotted to this Institute. These do not apply to ordinary papers, on subjects outside of iron and steel. It has been agreed between the two societies that each shall be free to publish in its own Transactions, in full, in part, or in abstract, such papers, presented by the other, as it may desire. Papers of this Institute, not relating to iron or steel, will be 'read by title' only at the joint sessions. But of such papers, if received, accepted and published according to the conditions stated below, pamphlet copies will be taken to London, for distribution to those interested in them, and to the technical journals.

"Rules and Suggestions

"1. All papers presented by this Institute at the joint sessions must have been printed beforehand. No such paper will be read in full. The author, if present, will be allowed fifteen minutes to indicate orally the important features of his paper, and an equal time to close its discussion.

"2. Contribution to the discussion of any such paper may be made in writing or orally; and the time allowed for their reading or oral presentation will be decided between the secretary and the author, with the understanding that, as far as possible, no one desiring to participate in the discussion shall be excluded by reason of the allowance of more than ten minutes to any other; that all remarks made in oral discussion (modified or amplified as the author may desire) shall be, immediately thereafter, furnished to the secretary in writing; and that acceptable discussion, whether presented at the meeting or not, will be subsequently published by the Institute.

"3. In order to secure valuable discussion, the papers

presented by this Institute should be published in preliminary form, and distributed to members of both societies, before the date of the meeting. Consequently, all papers concerning iron or steel, intended for such presentation, must be in the hands of the secretary before March 31, 1906, so that they may be examined, accepted, edited, published and distributed by June 1, 1906. These are the latest permissible dates. Those who can furnish manuscripts earlier (especially if they reside at a considerable distance from New York City, or if their papers are accompanied with illustrations), will greatly facilitate the work of the secretary and the printer by doing so.

" 4. Members proposing to offer papers of this class are earnestly requested to give immediate notice (stating the nature, length, etc., of the proposed papers) to the secretary, who will take pleasure in facilitating, by suggestion and advice, the work of their preparation. In view of the now acknowledged leadership of the United States in the production of iron and steel, papers descriptive and critical of modern American practice are deemed specially appropriate and desirable.

" 5. All the papers relating to iron or steel, received and accepted before March 31, 1906, will be printed as soon as possible, and distributed at or before the joint meeting, but precedence will be given in order of printing to those selected as most important and appropriate, and likely to elicit the widest and most profitable discussion. These will be sent in advance to the members of both societies interested in their subjects, and qualified to criticise them intelligently.

" 6. It is impossible to say beforehand exactly how many accepted papers will be presented for actual discussion at the joint meeting. Probably the thorough discussion of three, or perhaps four, will exhaust the available time. But the rest will be presented in print, with brief reference to their nature, and invitation of appropriate discussion by mail; and will be included, together with such discussion, in the Transactions of this Institute, and also placed at the disposal of the Iron and Steel Institute, for full or partial publication in the journal of that society.

" This occasion offers, therefore, an unusual opportunity, not only for contributions of international value to the arts and sciences connected with iron and steel, but also for the winning of international recognition for such services."

REVIEW OF THE IRON AND STEEL MARKET

There has been a general advance of from $1.00 to $1.50 in pig iron in all markets since our last report, while crude steel and finished steel products are substantially unchanged in price. There are expectations that pig iron will score further advances before the end of the year, reaching possibly $20 at furnace. Several finished steel products would have advanced before this had not the large producers steadfastly set their faces against such a movement.

Buying of finished steel products has in general exceeded production during the month, and mills are sold farther ahead than they were two months ago. Production, however, has been extremely heavy. If the October rate of pig-iron production is maintained to the end of the year, production will have amounted to about 22,900,000 gross tons for the whole year, or about 4,900,000 tons in excess of the best previous record. All this pig iron is going into immediate consumption.

Since the Pennsylvania railroad system placed orders for 21,000 steel freight cars, as noted in last report, the New York Central has bought 25,000 steel cars, and a number of smaller orders have been received, so that the steel car plants of the country are sold up through the first nine months of next year. The plate and shape orders against this work have been placed.

Pig Iron. — Buying of pig iron has been fairly large in all markets, although there has not been the rush which characterized the market in October. As a result of that movement, however, furnaces were so well sold up that on the light sales during November the market has advanced even more rapidly than it did in October. Southern pig iron has advanced about $1.50, northern foundry iron from $1.00 to $1.25 and Bessemer about $1.50. There is little iron available either north or south for delivery before the second quarter of next year. Prices are very firm as follows: F.o.b. valley furnace: Bessemer, $17.50; basic, $17.25; No. 2 foundry, $17.00 to $17.50; forge, $16.00 to $16.25.

Delivered Pittsburg: Bessemer, $18.35; basic, $18.10; No. 2 foundry, $17.85 to $18.35; forge, $16.85 to $17.10. F.o.b. Birmingham: No. 2 foundry, $14.50; gray forge, $13.25. Delivered Philadelphia: No. 2 X foundry, $18.00 to $18.50; standard gray forge, $16.25 to $16.50. Delivered Chicago: northern No. 2 foundry, $19.00 to $19.50; malleable Bessemer, $19.00 to $19.50; Lake Superior charcoal, $19.50 to $20.00. Freight: Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65; to Philadelphia by water, $3.50; by all-rail, $4.00.

Ferro-Manganese. — Largely on account of the troubles in the Caucasus, the supply of manganese ores has been reduced at a time when the demand is unusually heavy. Deliveries of ferro-manganese on contracts have been poor, and a number of consumers have been forced into the market at a time when there was scarcely any prompt metal to be had, the result being an unprecedentedly rapid advance. About the first of November the fairly large lots available for early delivery were sold, at about $65, delivered, for 80 per cent metal. Since then on sales of small lots the market has advanced rapidly, $75 being touched in the first fortnight of the month and $90 in the third week, and the market cannot now be definitely quoted. Late deliveries would not bring such high figures, but there is no interest in such deliveries at present, as contracts are not being filled as they should be and it is uncertain when there will be relief from the scarcity.

Steel. — The market has been almost nominal through the month, with no particular change in prices. A number of exchange deals have been made, but no large tonnages have sold in the open market. We continue to quote prices as follows: F.o.b. Pittsburg: Bessemer billets, $26; open-hearth, $27 to $28; forging billets, $30; sheet bars, long lengths, $27; wire rods, $32; chain rods, $33.

Rails. — There has been further booking of large rail contracts, and the western and southern mills are sold for practically the entire year 1906. The price for standard sections remains at $28 at mill. Light rails are scarce for any early delivery, and command a premium in some cases above the regular prices for later delivery, based upon $26 at mill for sections 25 to 45 pounds per yard.

Shapes. — A large tonnage continues to be booked. The large structural mills are sold almost through the first half of next year, with actual specifications in hand on most of the tonnage. Production will be increased in December and January by the completion of two new mills, one at Clairton by the Carnegie Steel Company and one at the South Chicago works of the Illinois Steel Company. These mills will have an output roughly estimated at about 10,000 tons each per month. Prices are unchanged for regular mill delivery, based on 1.70 cents for beams and channels, 15-inch and under, angles 2 x 3 to 6 x 6 inclusive and zees.

Plates. — The plate mills have large tonnages sold against steel car work through the first three quarters of next year, and are sold for their entire output until some time in the first quarter. The regular mill price remains at 1.60 cents for tank quality, quarter-inch and heavier.

Merchant Bars. — Iron bars have advanced in all markets, by about $2.00 a ton in the east and $1.00 a ton in the west. The market stands at 1.80 cents f.o.b. Youngstown and 1.85 cents, delivered, at Pittsburg and Chicago.

Sheets. — The American Sheet and Tin Plate Company advanced its prices on all sheet products 10 cents per hundred pounds, effective November 20. Many of the independent mills had already started quoting higher prices. An advance of 10 cents a box was made in tin plates. Practically all large buyers had covered before these advances, but they are holding as regards such business as comes up. We now quote on No. 28 gauge sheets, f.o.b. Pittsburg, 2.30 cents minimum on black and 3.35 cents minimum on galvanized, with single carloads sometimes bringing 5 cents a hundred additional. Tin plates are now $3.35 per box, net, for 100-pound cokes, f.o.b. Fittsburg.

Scrap. — The market has advanced rather sharply on light sales, the dealers absorbing scrap willingly and holding it for winter, when much higher prices are expected to prevail. We quote the market approximately as follows: Heavy melting scrap, $18.00; cast borings, $11.00; sheet scrap, $15.50; No. 1 wrought scrap, $20.00; No. 1 cast scrap, $15.50, all delivered, Pittsburg district.

Coke. — There has been no further advance in Connellsville coke on contracts for 1906 since the high prices which had been

reached at the time of our last report, while Connellsville furnace coke for prompt shipment has declined a trifle on account of two or three furnaces being temporarily out of blast. We quote for strictly Connellsville coke, net ton at ovens, $3.00 on furnace coke on contract and $2.90 to $3.00 on prompt coke, and $3.50 on foundry coke on contract and $3.75 to $4.00 for prompt shipment.

STATISTICS

German Pig-Iron Production. — The returns of the Association of Iron and Steel Producers show that the German production of pig iron in September and in the first nine months of the year has been as follows, compared with last year, the figures referring to metric tons of 2,204.6 pounds:

	September		First Nine Months	
	1904	1905	1904	1905
Foundry iron	163,302	168,841	1,359,345	1,379,000
Bessemer iron	23,175	34,634	310,790	315,614
Basic iron	523,042	618,472	4,777,728	5,170,527
Spiegeleisen	53,412	65,185	459,534	501,005
Forge iron	70,677	66,648	623,572	597,450
Totals	833,608	953,780	7,530,969	7,963,596

Belgian Pig-Iron Production. — Pig-iron production in Belgium in September showed an increase of 4,622 tons over the production in September of last year, making the gain for the nine-month period 23,835 tons. The production by grades has been as follows, in metric tons of 2,204.6 pounds:

	First Nine Months	
	1904	1905
Bessemer and basic	716,151	764,746
Forge pig	183,037	161,153
Foundry pig	79,150	76,274
Totals	978,338	1,002,173

World's Pig-Iron Production. — Official statistics have become available of pig-iron production in Sweden in 1904, showing the total to have been 528,525 metric or 520,173 gross tons. An estimate is made of Italian production in 1904 at 120,000 tons. Statistics of 1904 pig-iron production have been available for some time for the United States, Germany, United Kingdom, France, Russia, Belgium and Canada, and such production added to the production in Sweden and Italy makes a total of 42,969,810 gross tons, with Austria-Hungary and Spain

yet to be heard from, and an estimate to be made for various countries which do not make statistical returns. In 1903 such countries were credited with 1,918,462 tons, so that should there be no change in this direction the world's production of pig iron in 1904 would stand at 44,888,272 gross tons, against 45,894,713 gross tons in 1903, 43,324,068 gross tons in 1902, 40,100,000 gross tons in 1901 and 40,087,616 gross tons in 1900. The decline in the world's pig-iron production in 1904 was due to the United States and the United Kingdom, the former showing a decrease of 1,512,219 gross tons and the latter a decrease of 248,546 gross tons.

Russian Iron and Steel Statistics.* — Through the courtesy of Mr. Adolphe Wolski, of the Statistical Department of the Ministry of Finance of the Russian Government, we are enabled to give below the official statistics of the production of iron ore, coal, pig iron, steel ingots and castings, and steel rails in Russia and Finland for the last fifteen years.

Iron Ore. — The maximum production of iron ore in the Russian Empire was reached in 1900, when 6,112,090 metric tons were mined. The next highest years were 1899, when the production amounted to 5,890,900 tons, and 1904, when it amounted to 5,272,300 tons. In the following table the production of iron ore is given, in metric tons, from 1890 to 1904:

Years	Metric Tons	Years	Metric Tons	Years	Metric Tons
1890	1,795,663	1895	2,986,715	1900	6,112,090
1891	1,958,452	1896	3,321,786	1901	4,723,983
1892	2,044,106	1897	4,102,536	1902	3,987,303
1893	2,210,305	1898	4,536,217	1903	4,218,600
1894	2,524,610	1899	5,890,900	1904	5,272,300

Coal. — The production of coal in the Russian Empire was as follows from 1890 to 1904. The maximum production was reached in 1904.

Years	Metric Tons	Years	Metric Tons	Years	Metric Tons
1890	6,085,080	1895	9,098,800	1900	16,135,600
1891	6,223,450	1896	9,384,900	1901	16,507,240
1892	6,946,200	1897	11,210,524	1902	16,431,440
1893	7,610,600	1898	12,333,500	1903	17,818,000
1894	8,762,600	1899	14,311,200	1904	19,318,370

* " Bulletin," American Iron and Steel Association, September 15, 1905.

Pig Iron. — Although the production of pig iron in the Russian Empire in 1904 was the largest in its history the industry has made but little progress statistically since 1899, in which year the production was only 250,943 tons less than in 1904. In the following table the production of pig iron is given since 1890. Russia is a large importer of pig iron, her production in some years being only slightly in excess of her annual production of steel ingots and castings.

Years	Metric Tons	Years	Metric Tons	Years	Metric Tons
1890	927,214	1895	1,453,529	1900	2,936,191
1891	1,005,570	1896	1,607,490	1901	2,869,306
1892	1,072,651	1897	1,881,670	1902	2,597,435
1893	1,147,391	1898	2,243,081	1903	2,486,610
1894	1,348,615	1899	2,727,382	1904	2,978,325

Steel Ingots and Castings. — In the following table will be found the production of all kinds of steel ingots and castings in Russia from 1890 to 1904. Over two thirds of the steel now made annually in the Russian Empire is produced by the open-hearth process. The production of steel castings by the Bessemer and open-hearth processes amounts to from 35,000 tons to 40,000 tons annually. About 2,000 tons of steel ingots and castings are also annually produced by the crucible process. In addition, from 5,000 tons to 6,000 tons of steel are annually made by various minor processes. The growth of the Russian steel industry from 1890 to 1904 has been remarkably strong and steady.

Years	Metric Tons	Years	Metric Tons	Years	Metric Tons
1890	378,422	1895	880,451	1900	2,217,752
1891	440,212	1896	1,023,118	1901	2,230,000
1892	516,315	1897	1,225,526	1902	2,183,400
1893	633,120	1898	1,621,801	1903	2,410,938
1894	726,017	1899	1,903,000	1904	2,811,948

Steel Rails. — The production of steel rails in Russia has been as follows, in metric tons, from 1890 to 1904. The maximum production was reached in 1900, when 496,475 tons were rolled.

Years	Metric Tons	Years	Metric Tons	Years	Metric Tons
1890	166,156	1895	302,428	1900	496,475
1891	166,503	1896	398,848	1901	481,918
1892	193,338	1897	444,062	1902	382,152
1893	230,954	1898	468,787	1903	332,367
1894	250,190	1899	464,377	1904	401,541

Iron and Steel in Sweden.* — According to the report of Director-General Richard Akerman on the Swedish iron industry, the production of iron ore, which was 3,677,841 metric tons in 1903, was 4,084,647 tons in 1904, showing an increase of 406,806 tons, or 11.1 per cent. The production of coal in 1904 was 320,984 metric tons.

The output of pig iron was 506,825 metric tons in 1903, and 528,525 tons in 1904, an increase of 21,700 tons, or 4.3 per cent. There were 133 furnaces in blast in 1904; the average active period was 263 days, giving an average yield per furnace of 3,974 tons for the year, or 15.1 tons per day. The Swedish furnaces all use charcoal as fuel. The quantity of blooms made from pig iron in charcoal hearths — an industry now almost peculiar to Sweden — was 189,246 tons in 1904.

The production of steel ingots and direct castings was as follows, in metric tons:

	1903	1904		Changes
Bessemer	84,229	78,577	D.	5,652
Open-hearth	232,878	252,832	I.	19,954
Total	317,107	331,409	I.	14,302

Last year there were reported, in addition, 1,162 tons of crucible steel ingots and 951 tons of blister steel, bringing the total make of steel of all kinds up to 333,522 metric tons. The ratio of steel to pig iron last year was 0.63, a high figure.

The production of finished iron and steel in various forms is reported as follows, in metric tons:

Bars	181,775
Nail-plates and wire-rods	102,976
Other shapes	9,020
Plates	16,331
Tube-blocks and hollow-blooms	23,594
Total	333,696

Adding the charcoal blooms made direct from pig iron gives a total of 522,930 tons of finished or semi-finished products. In this total, however, there is some duplication, as a part of the charcoal blooms is converted into bars and wire-rods, though a quantity is also sold and exported in the form of blooms.

* "Engineering and Mining Journal," October 7, 1905.

The high quality of Swedish iron makes a strong export demand, not only for these blooms, but also for bars, wire-rods and other forms of iron and steel.

British Half Yearly Steel Statistics.* — The total output of Bessemer steel ingots in Great Britain in the first half of 1905, as ascertained by the British Iron Trade Association, was 1,019,887 tons, which compares with 865,683 tons in the first half of 1904 and with 911,670 tons in the first half of 1903.

The production of Bessemer steel rails in the first half of 1905 was 540,314 tons, against 523,771 tons in the first half of 1904. It will be observed that the output of steel rails has not increased to the same extent as the output of ingots, and that the quantity of steel rails produced is not much over one half that of the Bessemer ingots produced in the first half of 1905.

The output of open-hearth steel ingots in the United Kingdom in the first half of 1905 has been ascertained by the British Iron Trade Association to have been 1,980,095 tons, which is an increase of 309,966 tons on the production in the corresponding period of the previous year, or at the rate of nearly 620,000 tons of increase for the whole twelve months.

The output of open-hearth steel ingots in the first half of 1905 is considerably in excess of that of any previous half year, the nearest approach to it having been an output of 1,710,602 tons in the first half of 1902.

Production of Natural Gas in 1904.* — F. H. Oliphant has prepared a paper for the United States Geological Survey on the production of natural gas in this country in 1904. This production amounted approximately to 256,645,000,000 cubic feet, or 6,159,480 tons of 2,000 pounds. The value of this production was $38,496,760, which was an increase of $2,688,900 over the value of the production in 1903. The production of Pennsylvania alone was valued at $18,139,914, or 47 per cent of the entire value. Four States, Pennsylvania, West Virginia, Indiana and Ohio, produced 93.3 per cent of the entire value of natural gas produced in 1904. The total production in 1904 was greater than that of any previous year. Natural gas was produced in 1904 in twenty states and territories.

* " Bulletin," American Iron and Steel Association, November 15, 1905.

The value of natural gas produced and consumed in the United States in the last eight years has increased nearly threefold. It is remarkable that Pennsylvania, which was the first State to use natural gas on a large scale, has regularly-maintained a yearly increase for the last eight years, the product for 1904 being about three times the quantity marketed in 1897. West Virginia and Ohio have also shown a remarkable increase in the production of natural gas since 1897. Indiana has for the last two years shown a heavy decline in production. Alabama has for the first time entered the list of natural-gas producing States. Some natural gas is produced in Canada and consumed in the United States but is not included in the above statistics.

The large increase in the value of the production of natural gas in Pennsylvania in 1904 is remarkable when it is remembered that Pennsylvania is the oldest State producing natural gas in any large quantity. The increase has been derived from the deeply buried sands in Greene and Washington counties in the southwestern portion of the State, and from the counties of Armstrong and Clarion, where deeper producing sands have been developed in 1902 and 1903. A few small pools were secured in Potter County.

Some very large natural-gas wells were developed in Kansas in 1904, whose discovery was in part due to the large amount of drilling that was done in search of petroleum, and which, from all appearances, must soon put Kansas among the great natural-gas producing States.

Natural gas is produced in California, but the total production is comparatively small.

RECENT PUBLICATIONS

Sir Henry Bessemer, an Autobiography. 380 9 × 11-in. pages; illustrated. Offices of "Engineering." London. 1905. Price, $4.00. — We publish in full in this issue the chapter of this book entitled, "The Genesis of the Bessemer Process," which we consider a masterful description both as to clearness and technical accuracy of the evolution of this epoch-making invention. It will suggest the pleasure and instruction to be derived from the reading of Sir Henry Bessemer's autobiography. Few inventions, if any, have had a more momentous influence upon our material civilization, and few inventors have shown greater ingenuity, clearness of mind and logical sequence in bringing to a triumphant climax the working of a sound conception. Sir Henry Bessemer's biography is refreshing and inspiring reading, relating as it does an eminently useful and successful life, free from those melancholy chapters which form too often a conspicuous part of an inventor's life. The book is divided into twenty-one chapters bearing the following titles, the concluding chapter having been written by the publishers with the assistance of Sir Henry Bessemer's son: Early Days; The Reward of Invention; Compressing Plumbago Dust; Casting Type, Type-Composing Machine, etc.; Utrecht Velvet; The Manufacture of Bronze Powder; Improvements in Sugar Manufacture; A Holiday in Germany; Improvements in Glass Manufacture; The Exhibition of 1851; Early Gunnery Experiments; The Genesis of the Bessemer Process; The Bessemer Process; Bessemer Steel and Colonel Eardley Wilmot; The Bessemer Process and the War Office; Bessemer Steel; The Armstrong Controversy; Bessemer Steel Guns; Cast Steel for Ship-building; Manganese in Steel-Making; Ebbw Vale; The Bessemer Saloon Steamship; Conclusion. The publishers are to be congratulated in bringing forward so interesting a book in so attractive a form, both the typography and engraving being a highly creditable example of the best work of printer's and engraver's arts. The book should appeal not only to metallurgists and

engineers, but also to a very large class of thoughtful and appreciative readers.

Contribution à l'Étude de la Fragilité dans les Fers et les Aciers (Contribution to the Study of Brittleness in Iron and Steel). 482 9 × 11-in. pages; illustrated. Paper covers. Société d'Encouragement pour l'Industrie Nationale. Paris. 1904. Price, 20 francs. — This important volume is chiefly made up of reprints from the bulletin of the "Société d'Encouragement pour l'Industrie Nationale," dealing with the brittleness of iron and steel and the testing methods best adapted to its detection. It is stated in a short preface that during the last fifteen years numerous investigations have been conducted, especially in France, into the brittleness of steel. They appeared in various publications and some of them are to-day difficult to procure. The "Société d'Encouragement" thought that a reprint of these articles in book form would be of much value to metallurgists and constructing engineers. The society was assisted in its task by six large railway companies, to whom her thanks are due for their generous support. The articles reprinted here are by Messrs. Ast, Aucher, Barba, Brinnell, Brustlein, Charpy, André Le Chatelier, Henry Le Chatelier, Considère, Fain, de Fréminville, Frémont, Godron, Guillery, Huillier, Leblant, Mesnager, Osmond, Ridsdale, Vanderheym and Wahlberg. Under the title of "Brittleness of Steel," and as an introduction to the book, Prof. Henry Le Chatelier gives a very able and instructive résumé of the most important results of these investigations. The Société d'Encouragement is certainly entitled to much credit for her enterprise and her leadership in promoting the scientific study and scientific treatment of the metal which forms the very foundation of our material civilization.

Technical Methods of Ore Analysis, by Albert H. Low. 273 6 × 9-in. pages; illustrated. John Wiley & Sons, New York. 1905. Price, $3.00. — The following extracts from the author's preface will give an accurate idea of the scope and character of the book:

"This book is primarily intended as an aid to the technical chemist, but it is hoped it may also prove useful to the student desiring to become acquainted with technical methods.

"It is a common experience with technical chemists to receive a sample of material with instructions to return the percentage of some constitutent whose technical determination is more or less unfamiliar under the given conditions. In such a case the chemist has recourse to his books and too frequently is quite unable to find a method that is exactly adapted to the material in hand, or that begins at the beginning and tells him just how to proceed. He is thus left to work out his own salvation, possibly at the expense of much valuable time.

"In this book an attempt has been made to supply the want thus indicated by describing methods that are adapted to the cases most likely to be met in practice, although it is sometimes practically impossible to devise a short technical method that will meet every probable case.

"It has been my aim to make the descriptions so minute and complete that if the operator will follow them exactly he can scarcely fail to obtain satisfactory results.

"Some of the methods in the following collection have been devised by myself, mainly on the basis of previously well-known facts; some are compilations of the work of others and some are modifications of existing methods. I have endeavored to give proper credit in all cases."

The methods appear to be very methodically and clearly described and it certainly seems as if Mr. Low's book should be found of much assistance by analytical chemists. The typography of the book as well as the paper and binding are excellent.

Cours d'Exploitation des Mines, third edition, by Haton de la Goupillière, with revisions and additions by Jean Bès de Berc. Volume I. 1,002 $6\frac{1}{2} \times 10$-in. pages; illustrated. Paper covers. Vve. Dunod. Paris. 1905. Complete in three volumes. Price, 90 francs. — This is the third and considerably enlarged edition of a book of universal reputation. There are probably very few living mining engineers who have not at least consulted this classical work during their student days, and a large number have used it as a textbook. In this new edition the subject has been brought up to date by Jean Bès de Berc, himself a distinguished engineer. It is to be complete in three volumes. The first volume which we have before us deals with the discovery of Mineral Deposits, Breaking Ground and Drilling,

Shafts and Galleries. The second volume will deal with various methods of mine exploitations and the third volume with Drainage, Ventilation and Ore Dressing. The publishers deserve the gratitude of the mining professions for bringing forward this modernized edition of so important a book.

Transactions of the Institution of Mining and Metallurgy. Volume XIII (1903–1904). Edited by Arthur C. Claudet and C. McDermid. 568 6 × 8½-in. pages; illustrated. Paper covers. E. and F. N. Spon. London. — This volume contains the minutes of the meetings held during the thirteenth session (1903–1904) of the Institution of Mining and Metallurgy. Among the many valuable papers read before the Institution we note the following as most likely to be of interest to our readers: The Equipment of Laboratories for Advanced Teaching and Research in the Mineral Industries, by Henry C. Jenkins; Iron-Ore Mining in Scandinavia, by W. Fischer Wilkinson; The Microscope as an Aid in Copper Refining, by H. Nestor Schurmann; A Graphic Method for the Computation of Blast-Furnace Charges, by C. O. Banister.

Smithsonian Institution, annual report of the Board of Regents for the year ending June 30, 1904. 804 6 × 9-in. pages; illustrated. Government Printing Office. Washington, D. C. 1905. — The present issue of this valuable yearly publication contains the usual number of reprints from important scientific papers and fine illustrations covering a wide range of subjects.

The Universal Directory of Railway Officials, 1905. Compiled under the direction of S. Richardson Blundstone, editor of the "Railway Engineer." 667 5½ × 8½-in. pages. — The Directory Publishing Company. London. Price, 10 shillings. — This is the eleventh year of publication of this directory, the value of which will readily be appreciated when it is considered that it contains a list of the principal officers of every railroad in the world, with a brief description of the equipment, gauge and mileage of each road. The tram lines of Great Britain are also included. The contents are compiled entirely from official sources.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

801,136. Ingot Stripper. — Dwight B. Cheever, Chicago, Ill., assignor to Whiting Foundry Equipment Company, Harvey, Ill., a corporation of Illinois.

801,143. Process of Preparing Dust Ores for Blast Furnaces. — Heinrich E. Eich, Giessen, Germany, assignor to the firm of Fellner & Ziegler, Frankfort-on-the-Main, Bockenheim, Germany.

801,144. Preparing Dust Ores for Blast Furnaces. — Johann C. Fellner, Frankfort-on-the-Main, Germany, assignor to the firm of Fellner & Ziegler, Frankfort-on-the-Main, Bockenheim, Germany.

801,229. Method of Casting Metals. — James Eaton-Shore, Rugby, England, assignor to Willans & Robinson, Ltd., Rugby, England.

801,274. Process of Converting Steel-Scrap into Iron. — Edward M. Schulz, Sergeants Hall, and George W. Helmlinger, Pittsburg, Pa.

801,339. Compound for Hardening or Case-Hardening Iron or Steel. — Gustav Reininger, Berlin, Germany, assignor to the firm of Cyanid-Gesellschaft mit Beschraenkter Haftung, Berlin, Germany.

801,347. Water-Cooled Furnace Valve. — Francis H. Treat, Pittsburg, Pa.

801,453. Molten-Metal Conductor for Cupolas, Etc. — Carmi L. Glover, Newcastle, Pa.

801,500. Apparatus for Making Steel. — Frank E. Young, Canton, Ohio.

801,646. Apparatus for Preparing Ingot-Molds for the Casting Operation. — Hugo Carlsson, Stockholm, Sweden, assignor of one half to James H. Le Fevre, Buffalo, N. Y.

801,656. Process for the Deoxidation of Ingot-Iron, Ingot-Steel, Etc. — Richard Eichhoff, Essen-Rüttenscheid, Germany, assignor by mesne assignments to Elektrostahl Ges. M. Beschr. Haft., Remscheid-Hasten, Germany.

801,842. Compound for Coating Iron and Steel. — Nicholas A. Bibikov, New York, N. Y., assignor of one fourth to Henry Connett, New York, N. Y.

801,947. Magnetic Separator. — John P. Wetherill, South Bethlehem, Pa., and Henry A. J. Wilkens, New York, N. Y., assignors by mesne assignments to Wetherill Separating Company, a corporation of New Jersey.

802,030. Bell Operating and Controlling Mechanism for Blast Furnaces. — John P. Coleman, Edgewood, Pa., assignor to the Union Switch & Signal Co., Swissvale, Pa., a corporation of Pennsylvania.

802,131. Metal-Handling Device. — Henry Aiken, Pittsburg, Pa.

802,151. Tilting Furnace. — Francis H. Treat, Pittsburg, Pa.

802,170. Magnetic Ore-Separator. — Richard R. Moffat, Brooklyn, N. Y., assignor to Imperial Ore Separator Company, a corporation of New York.

802,176. Blast Furnace. — Samuel B. Sheldon and Alexander K. Hamilton, Buffalo, N. Y.

802,931. Gas-Producer. — Jerome R. George, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass., a corporation of Massachusetts.

803,337. Metallurgical Furnace. — Harry H. Goodsell, Leechburg, Pa.

803,597. Device for Operating Furnace Doors, Gates, Etc. — Joseph S. Hood, Stahlstown, Pa.

803,673. Apparatus for Rolling Sheet and Tin Plate. — Percy E. Donner, Columbus, Ind.

803,674. Apparatus for Rolling Sheet and Tin Plate. — Percy E. Donner, Columbus, Ind.

803,745. Apparatus for Rolling Sheet and Tin Plate. — Percy E. Donner, Columbus, Ind.

803,763. Bearing for the Rolls of Rolling Mills. — John T. Horner, Newcastle, Pa.

803,886. Treatment of Iron Ores, Etc. — Carleton Ellis, New York, N. Y.

804,023. Coupling Box for Rolls. — William C. Millhizer and Frederick McQuiston, Pittsburg, Pa.

804,080. Apparatus for Making Steel and Other Metals. — Edwin C. Wills, Trenton, N. J.

804,193. Process for Manufacturing Briquettes. — Gottfried Hoepfner, Bleckendorf, Germany, assignor to Willy von Lewinski, Breslau, Germany.

GREAT BRITAIN

7,599 of 1905. Refractory Lining for Furnaces. — J. Bach, Riga, Russia. Making refractory linings for furnaces by mixing 20 parts of pure hydrate of alumina with 80 parts of ordinary fire-clay and applying the mixture, while moist, to the thickness of an inch and then burning.

9,774 of 1905. Blast-Furnace Blowing. — J. W. Dougherty, Steelton, Pa. A method of blowing blast furnaces without the liability of explosions.

9,199 of 1905. Recovery of Iron from Slag. — O. Thiel, Landstuhl, Germany. An improved furnace and process for recovering iron from slags containing much oxide of iron.

28,295 of 1904. Blast-Furnace Gas Scrubber. — J. E. Thornycroft, London. Improved water sprays for removing dust and tarry matters from blast-furnace and other gases.

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